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CORRECTION

Monthly Weather Review:

Index for 1920: Page xix, under "Woolard, Edgar William," the fifth entry, "Light scattering by air and the blue color of the sky. 220." should be credited to "Wood, R. W."

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

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SEPTEMBER, 1930

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THE GREAT DROUGHT OF 1930 IN THE UNITED STATES

By ALFRED J. HENRY

[Weather Bureau, Washington, October, 1930]

This paper is chiefly concerned with the various aspects of the drought as a meteorological phenomenon. Unfortunately there is no yardstick by which one drought may be compared with another except at the cost of very great labor; even then in many cases the results would be unsatisfactory because the detailed records of previous droughts in this country have not been preserved in convenient form for reference.

The term "drought" is loosely used to mean any shortage of rainfall that may extend over an indefinite number of days without a quantitative scale as to the amount that shall be necessary to warrant the use of the expression "drought."

A search through the literature of the Weather Bureau reveals the fact that drought is defined in Circular M (fifth edition) Instructions to Marine Meterological Observers, as follows "Drought: A protracted period of dry weather."

Gen. A. W. Greely, the last military chief of the Federal weather service was the first to point out the need of a quantitative scale for use in connection with the term "drought." He suggested that that term be used only for those parts of the country where the average precipitation exceeds an inch in each month; he further remarked [1] that "from an examination of the records it appears that droughts are very severe whenever the rainfall for one or more months is less than 50 per cent of the average amount and it is suggested that the drought unit indicate a deficiency to be determined with reference to the average monthly amount during the time in which the drought prevails."

Henry [2] in 1906, proposed and used a definition of "drought" substantially as follows "Drought: A drought is considered to exist whenever the rainfall for a period of 21 days or longer, is but 30 per cent of the average for the time and place." That definition takes account of the fact that rainfall averages differ from place to place and from one season the of year to another.

In the Atlas of American Agriculture, section on precipitation, while the difficulties of formulating a definition of drought are fully set forth no effort seems to have been made to effect a compromise, since in the nature of the case an arbitrary definition without objection of one form or another is not possible.

The British Rainfall Organization defines "drought" as follows: "Drought, dryness due to lack of rain." According to the classification of that organization an *absolute drought* is a period of more than 14 days without one hundredth of an inch of rain on any day, and a *partial drought* is a period of more than 28 consecutive days, the mean rainfall of which does not exceed one hundredth of an inch per day or for the 28 days at most barely a quarter of an inch.

The drought statistics compiled by Henry [3] show that scarcely a year passes, even in the more humid regions of the East without a more or less severe drought in some part of the United States according to the definition he adopted.

In the publication cited drought statistics for a single station, Washington, D. C., for the 33-year period 1871–1903, were published. Using the same method of compilation, the table there given has been brought down to date and appears below as Table No. 1. It presents a chronological list of droughts in Washington, applicable to adjacent areas on a uniform plan for 60 consecutive years.

TABLE 1.—*Periods of deficient rainfall at Washington, D. C., 1871–1930*

Year	Precipitation during 2 weeks previous to drought			Duration of drought	Number of days	Precipitation during drought		
	Amount	Normal	Percentage			Amount	Normal	Percentage
	Inches	*Inches*				*Inches*	*Inches*	
1871	3.0	1.6	188	From May 11 to May 31	21	0.1	1.4	7
	1.9	2.1	91	From Aug. 1 to 23	23	.7	3.0	23
1872	2.0	1.8	111	From June 17 to July 31	45	1.3	6.5	20
1873	4.8	1.7	282	From May 12 to June 27	47	1.4	6.2	23
	1.4	1.8	78	From July 2 to 26	25	.8	3.7	22
1874	3.0	1.8	167	From June 13 to July 9	27	.9	3.8	24
	2.0	2.0	100	From July 12 to Aug. 22	42	1.0	5.9	17
	5.8	1.7	341	From Sept. 20 to Oct. 31	32	.3	3.2	9
1875	1.4	1.6	88	From May 5 to June 4	31	.6	4.0	15
	1.5	1.8	83	From June 8 to July 14	37	1.4	5.2	27
	1.9	1.8	106	From Sept. 20 to Oct. 15	26	.6	2.8	21
1876	1.6	1.9	84	From June 29 to July 29	31	1.0	4.6	22
	3.5	1.6	219	From Oct. 2 to 22	21	.5	2.1	24
1877	2.2	1.9	116	From Aug. 14 to Sept. 5	23	.6	2.9	21
1878	3.9	1.8	217	From Sept. 14 to Oct. 17	34	.6	3.7	16
1879	3.2	1.8	178	From June 12 to July 24	43	1.1	6.2	18
	6.7	1.8	372	From Aug. 27 to Oct. 20	55	1.8	6.3	29
1880	2.9	1.8	161	From June 17 to July 19	33	1.0	4.8	21
	3.4	1.8	189	From Sept. 10 to Oct. 3	24	.5	2.8	18
1881	3.4	2.0	170	From July 9 to Sept. 9	63	2.0	8.6	23
	2.2	1.8	122	From Sept. 17 to Oct. 23	37	1.0	4.0	25
1882	3.6	1.8	200	From June 2 to 30	29	1.1	3.9	28
	2.7	2.0	135	From Aug. 3 to 25	23	.8	3.0	27
	4.4	1.7	259	From Sept. 28 to Oct. 31	34	.5	3.4	15
1883	3.5	2.1	167	From July 25 to Aug. 14	21	.7	2.9	24
1884	4.1	2.1	195	From Aug. 1 to Oct. 31	92	2.9	10.8	27
1885	3.7	1.7	218	From Sept. 6 to Oct. 1	26	.5	3.2	18
1886	6.0	2.0	300	From Aug. 2 t Aug. 29	28	.3	3.6	6
	1.9	1.8	106	From Sept. 10 to Oct. 25	46	1.2	5.0	24
1887	1.7	1.9	89	From Aug 13 to Sept. 10	29	.7	3.6	19
	1.2	1.7	71	From Sept. 29 to Oct. 19	21	.4	2.1	19
1888	2.8	1.8	156	From June 1 to 22	22	.8	2.9	28
	3.9	2.1	186	From July 14 to Aug. 7	25	.9	3.6	25
	5.8	1.8	322	From Sept. 19 to Oct. 18	30	.7	3.2	22
1889	6.4	2.0	320	From Aug. 10 to Sept. 11	33	.9	4.2	21
1890	1.9	1.8	106	From June 24 to July 23	30	.9	4.0	22
1891	3.0	2.1	143	From July 30 to Aug. 20	22	.7	3.1	23
	5.2	1.8	289	From Sept. 7 to Oct. 18	42	.8	4.6	17
1892	3.4	1.8	189	From May 28 to June 26	30	1.0	4.0	25
	2.9	2.1	133	From Aug. 1 to Sept. 12	33	1.0	5.5	18
	3.4	1.7	200	From Sept. 24 to Oct. 21	38	.3	3.9	8
1893	2.3	1.8	128	From June 3 to Aug. 3	62	2.5	8.8	28
1894	2.2	1.8	122	From May 24 to July 21	59	1.8	8.2	22
	2.4	2.0	120	From Aug. 5 to Sept. 16	43	1.5	5.5	27
1895	2.2	2.0	110	From July 29 to Oct. 30	94	3.1	11.1	28
1896	1.2	1.8	67	From June 15 to July 5	21	.8	2.9	28
	2.3	2.1	110	From July 23 to Aug. 12	21	.7	2.9	24
	2.1	1.7	124	From Sept. 6 to Oct. 31	56	1.8	6.1	30
1897	2.3	1.9	121	From Aug. 12 to Sept. 22	42	1.3	5.3	25
1898	3.3	1.8	183	From May 17 to July 17	62	2.1	8.5	25
	8.3	1.9	437	From Aug. 14 to Oct. 17	65	1.9	7.6	25

[1] Greely, A. W., American Weather, New York, 1888, p. 246.
[2] Henry, Alfred Judson, and others, Weather Bureau Bulletin, Q., Climatology of the United States, 1906, p. 54.
[3] Loc. cit. pp. 52–56.

TABLE 1.—*Periods of deficient rainfall at Washington, D. C., 1871–1930*—Continued

Year	Precipitation during 2 weeks previous to drought			Duration of drought	Number of days	Precipitation during drought		
	Amount	Normal	Percentage			Amount	Normal	Percentage
	Inches	*Inches*				*Inches*	*Inches*	
1899	1.6	1.8	89	From June 13 to July 4	22	.9	3.0	30
	3.2	1.9	168	From Aug. 16 to Sept. 10	26	.6	3.3	18
1900	7.0	1.8	389	From June 18 to Aug. 19	63	2.1	8.9	24
	1.7	1.8	94	From Aug. 25 to Sept. 14	21	.5	2.7	19
1901	4.5	2.1	214	From July 15 to Aug. 5	22	.7	3.2	22
	2.4	1.8	133	From Aug. 25 to Sept. 27	34	.9	4.2	21
	1.2	1.6	75	From Oct. 4 to 31	28	.6	2.8	21
1902	2.4	1.8	133	From May 26 to June 15	21	.7	2.7	26
	3.0	2.1	143	From June 27 to July 17	21	.8	3.1	26
	2.1	2.1	100	From Aug. 7 to Sept. 2	27	.6	3.4	18
1903	2.1	1.7	124	From Aug. 31 to Oct. 6	37	1.2	4.4	27
1904	4.5	2.5	184	Aug. 3 to Sept. 13	42	1.2	5.4	23
	5.0	1.8	287	Sept. 16 to Oct. 20	34	.6	3.4	18
1905	2.2	1.7	123	Sept. 12 to Oct. 10	30	.2	3.4	6
1906	2.8	1.7	165	Apr. 16 to May 26	41	.8	4.7	16
	8.5	2.0	425	Sept. 1 to Sept. 30	30	.6	3.6	17
1908	1.6	1.7	94	Apr. 12 to May 3	22	.6	2.3	26
	1.6	2.0	180	June 16 to July 20	38	.6	4.8	12
	5.9	1.5	393	Sept. 7 to Sept. 27	21	0	2.7	0
	1.6	1.8	89	Sept. 29 to Oct. 28	29	.5	2.8	18
1909	2.4	1.9	126	Sept. 25 to Nov. 22	59	.9	5.6	16
1910	1.1	2.3	48	Aug. 1 to Aug. 31	31	1.3	4.4	29
	1.7	1.9	90	Sept. 7 to Oct. 6	28	.5	3.4	15
1911	1.5	1.4	93	Apr. 23 to May 29	37	.2	4.3	5
1912	3.0	2.3	130	Aug. 1 to Aug. 28	28	1.1	3.8	29
	3.2	1.6	200	Oct. 1 to Nov. 6	37	.9	3.7	24
1914	2.0	1.4	143	Apr. 27 to May 26	30	.9	3.6	25
	.7	1.8	41	May 28 to June 18	21	.8	3.1	26
	4.2	1.8	233	Aug. 30 to Sept. 30	32	.7	3.8	18
1915	.7	1.5	49	Apr. 13 to May 11	29	.2	3.1	7
1917	.9	1.6	55	Sept. 9 to Oct. 4	26	.5	2.8	17
1918	2.6	2.1	125	Sept. 22 to Oct. 29	38	.5	3.6	14
1921	1.4	1.9	74	June 1 to June 25	25	.5	3.5	14
	1.1	2.2	50	July 30 to Sept. 1	34	1.1	4.9	22
1922	1.2	1.2	100	Oct. 11 to Nov. 30	51	.7	3.9	18
1923	1.8	2.1	86	Sept. 24 to Oct. 21	27	.5	2.8	18
1924	2.8	2.0	140	July 10 to Aug. 8	29	.6	4.8	12
	6.8	1.6	428	Oct. 1 to Nov. 14	45	.5	4.3	12
1926	1.2	1.8	67	Apr. 1 to May 13	43	.8	4.8	17
1929	2.4	1.8	134	July 2 to Sept. 4	65	2.0	9.3	21
1930	2.8	1.4	200	Apr. 19 to May 13	24	0	2.7	0
	1.4	1.9	74	July 16 to Oct. 31 [1]	115	2.6	14.8	18

[1] The drought in Washington, D. C., and surrounding areas in Maryland and Virginia, had not been broken on this date.

The economic results of drought can not always be measured by the shortage in rainfall alone, hence the interpretation of the figures in the table is not easy. It is obvious that a deficiency amounting to 70 per cent of the normal rainfall in regions of abundant precipitation is not as serious as a deficiency of the same amount in places where the total rainfall is barely sufficient for the growth of staple crops.

The moisture content of the soil at the beginning of the drought is always an important consideration; there are added, to the table, therefore, figures showing the amount of rain that fell in the two weeks immediately preceding the drought. These figures are quite significant in the interpretation of the severity of the drought in each case.

It is a rather striking fact that for the years 1871–1903 51 out of a total of 62 cases had from 100 to 200, 300, and in extreme cases 400 per cent of the normal rainfall in the two weeks immediately preceding the beginning of the drought.

It is a matter of regret that time did not permit the examination of each individual case in order to determine the nature of the rains, whether as daily showers for several days or as a single torrential rain. If the latter then much of the rain would become surface run-off and be lost as a stimulus to vegetable growth.

Considering the whole period of 60 years covered in Table No. 1 it will be seen that in 69 out of the total of 93 droughts the rainfall immediately preceding them was 100 or more per cent of the normal for the time and place. That number is considerably greater than would be indicated by chance alone. The apparent explanation is that a long-continued showery period or a single torrential rain exhausts the moisture content of the atmosphere for the time and place to such an extent that further precipitation becomes more and more difficult until a fresh supply of saturated or nearly saturated air is brought in.

Examples of very great contrasts between the rainfall of short periods of time are numerous, only one will be given. In the two weeks prior to July 16, 1874, 7.4 inches of rain fell at Vicksburg, Miss., and in the 69 days immediately following the total fall was but 0.8 inch.

The longest period of deficient rainfall of which notice has been taken occurred at Shreveport, La., from June 14 to October 31, 1883, when the total rainfall for 141 days was but 22 per cent of the normal.

The distribution of deficient rainfall periods by months is given below for the two periods 1871–1903 and 1904–1930.

	1871–1903	1904–1930
	Per cent	*Per cent*
Number that began before Apr. 15	2	10
Number that began between Apr. 16 and May 15	10	13
Number that began between May 16 and June 15	13	6
Number that began between June 16 and July 15	17	10
Number that began between July 16 and Aug. 15	20	19
Number that began after Aug. 15	38	42

CAUSES OF THE DROUGHT

Very few persons realize the difficulty of attempting to analyze the cause or causes of prolonged heat and drought. While they may have a common cause it can not be said that the one is the cause of the other; this can be said however, viz, that drought has a tendency to perpetuate itself and high temperature is a valuable adjunct.

Percentage of normal rainfall, 1930

States	January	February	March	April	May	June	July	August	September	January to September	March to August	July and August
Kentucky	112	101	46	33	73	*48*	*50*	60	86	*68*	*47*	*48*
Maryland and Delaware	82	68	59	74	62	83	*37*	*26*	44	*58*	*55*	51
Virginia	80	48	56	67	65	77	39	*40*	41	*56*	*56*	*39*
Missouri	221	81	45	53	73	79	*24*	54	109	75	*57*	*59*
Illinois	208	104	48	79	46	87	*31*	57	101	78	*58*	44
Indiana	209	98	47	73	45	68	52	63	116	82	*58*	57
West Virginia	49	85	82	55	56	*64*	*42*	54	48	*59*	*59*	*48*
Ohio	162	110	81	65	50	60	*40*	68	91	77	*60*	53
Louisiana	166	78	78	29	132	*15*	61	89	180	89	66	74
Arkansas	223	117	47	*29*	200	*28*	*19*	70	121	95	68	*44*
North Carolina	94	33	65	59	76	98	62	50	90	69	68	56
Tennessee	105	94	89	37	134	*35*	54	65	106	*79*	69	59
Pennsylvania	68	101	86	80	76	102	51	*55*	72	*75*	*71*	*45*
Michigan	118	104	75	71	96	109	47	27	69	77	71	37
Alabama	88	43	98	34	96	46	73	77	196	80	72	75
Mississippi	107	69	71	23	208	*15*	52	74	156	81	72	62
South Carolina	125	26	86	70	68	91	82	42	110	76	72	62
North Dakota	54	241	*11*	91	103	88	40	64	62	76	73	51
Montana	57	82	103	121	59	58	68	90	114	79	76	77
Oregon	68	104	55	97	123	61	11	43	96	82	76	28
Minnesota	88	171	44	52	136	94	71	*54*	120	87	77	54
New Jersey	81	78	66	64	74	113	86	67	56	76	78	77
Texas	99	82	84	60	141	66	41	59	67	78	78	50
Washington	46	129	79	91	105	92	11	24	80	82	80	18
South Dakota	88	101	50	100	90	77	34	118	76	80	80	72
Iowa	125	55	50	90	81	130	39	70	63	79	81	54
Oklahoma	173	97	27	80	136	93	38	59	65	84	81	49
Wisconsin	94	120	74	79	91	133	70	32	84	85	82	52
Georgia	118	32	121	91	65	87	100	36	173	88	84	70
Kansas	148	27	20	109	115	98	60	92	104	90	89	75
California	97	65	85	92	134	10	22	80	100	86	90	53
New York	107	63	117	70	103	117	76	63	84	88	90	69
New England	79	64	127	50	107	102	102	66	48	83	92	83
New Mexico	117	37	98	58	99	76	132	86	68	91	97	110
Idaho	71	120	84	114	131	66	54	181	114	101	103	120
Nebraska	140	54	38	150	145	85	45	147	77	102	106	92
Colorado	155	68	67	57	134	49	140	160	72	103	107	149
Wyoming	95	82	90	55	108	70	90	331	61	103	112	191
Florida	126	99	241	131	105	150	*62*	62	126	115	113	*62*
Utah	134	84	77	69	129	74	121	214	162	119	115	172
Nevada	128	75	67	101	256	32	43	182	214	121	122	119
Arizona	174	41	181	65	269	118	144	103	80	123	135	124
United States [1]												
Average precipitation	2.6	1.7	2.0	1.8	3.2	2.3	1.8	2.0	2.7	20.1	13.1	3.8
Normal	2.3	2.2	2.4	2.5	2.9	2.9	2.8	2.6	2.4	23.0	16.1	5.4
Percentage of normal	113	77	83	72	110	79	64	77	112	87	81	70

[1] State means weighted by respective areas.
Italic figures indicate least precipitation of record.

The present shortage of rain began in December, 1929; that shortage, however, was in no wise different in magnitude or geographic distribution than occurs practically every year in some part of the country. No one could foresee at the time that the drought would continue for 10 months and spread to every State east of the Rocky Mountains except Florida.

Table 1 and the text up to the paragraph beginning "In searching for" is reprinted from Weekly Climate and Crop Bulletin of October 14, 1930.

PRECIPITATION IN THE UNITED STATES, FROM JANUARY TO SEPTEMBER, 1930

The table above summarizes, by months and other periods, precipitation data for the United States from January to September, inclusive, of the current year. The data represent final and complete figures for all stations maintained by the Weather Bureau, some 5,000 in number, except that in the case of September a few late reports may make slight changes in the State means. The table is arranged relative to deficiencies in precipitation for the spring and summer combined, March to August. It also includes a summary for the country, as a whole, obtained by weighting the respective State means on a relative area basis; these represent very closely the true means for the entire country. *Italic* figures indicate in all cases the least precipitation of record for the month or period.

Considering the New England States as a unit, and also Maryland and Delaware, the data represent 42 States. Of these, only 19 had deficient precipitation in January, with no previous low records broken. In February, 29 States had precipitation below normal, with no new low records. In March, 36 had means below normal, with one previous low record, North Dakota, broken. In April, 35 States had less than normal rainfall, with Arkansas alone having the lowest of record. In May, rainfall was generally greater, with only 20 States, or less than half the total number, having deficiencies, and no new low records established.

June was much drier than May, with 33 States reporting deficiencies in precipitation, and 6, Arkansas, Kentucky, Louisiana, Mississippi, West Virginia, and Tennessee, exceeding the previous low records. July was the driest of the nine months, with the rainfall in 36 States deficient, and Virginia, Maryland, West Virginia, Kentucky, Ohio, Illinois, Missouri, Florida, and Arkansas having the least of record. In addition, July was extremely warm in most sections. Every State had maximum temperatures of 100°, or higher, with the previous high records broken in Alabama, Florida, Indiana, Kentucky, Maryland, Mississippi, Tennessee, Virginia, and West Virginia, and equalled in Louisiana, New Mexico, and South Carolina. On the other hand, minimum temperatures were low in some States, with freezing, or below, reported in 11 of the 42.

In August, 35 States had deficient precipitation, with Virginia, Maryland, Pennsylvania, and Minnesota having the lowest of record. The first half of this month continued warm, and again every State had maximum temperatures of 100°, or higher; there was also some abnormally cool weather, with 19 of the 42 States reporting minimum temperatures of freezing, or below, and in one case as low as 10° below freezing. In September, much of the droughty area of the interior of the country was relieved, but, at the same time, 24 States had less than normal rainfall, though no previous low records were broken.

For the country, as a whole, January, with 113 per cent of normal rainfall, was relatively the wettest month, but was closely followed by September and May, with 112 and 110 per cent, respectively. All other months had deficient rainfall. July was the driest, with 64 per cent of normal, followed by April, with 72 per cent, and February and August, with 77 per cent. The records of normal rainfall for the country, as a whole, show a quite uniform monthly distribution for the nine months, the maximum being 2.9 inches for May and June and the minimum 2.2 inches for February.

For the entire period, April to September, West Virginia, Maryland, Virginia, Kentucky, Pennsylvania, and Tennessee had the least rainfall of record, while Ohio and Michigan had the least since 1895, and Missouri since 1901. In the case of West Virginia, the seasonal total was 35 per cent below the previous low record; in Maryland, 22 per cent; Virginia; 18 per cent, and Kentucky, 13 per cent. For the spring and summer months combined, March to August, the table shows that nine States had the least rainfall of record, while eight broke the previous low record for July and August combined.

In searching for pronounced abnormalities of the weather in distant regions that may or may not have contributed to the drought in continental North America, attention is first directed to a persistent and rather pronounced depression of the barometer over the northeastern North Atlantic Ocean, that prevailed from October, 1929, to February, 1930, as illustrated by the readings at Lerwick, Shetland Islands, and the west coast of Ireland as at Valencia. The upper half of the North Atlantic was exceptionally stormy during the first and third decades of December, 1929, as might be expected from the persistent low pressure at Lerwick and Valencia.

Considering now the pressure distribution over the northeastern North Pacific for the same month it is to be noted that while the reverse pressure conditions prevailed over the first half of the month, the high pressure gave way to very low pressure 28.76 inches at Dutch Harbor on the 27th and 28.82 at Kodiak on the 28th. The Aleutian LOW in January, 1930, was displaced far to the south-southwest and high pressure prevailed over the northeastern North Pacific and coastal Alaska, Kodiak 0.56 inch above normal and Juneau 0.45, a complete reversal from conditions in January.

The high pressure over northeastern Pacific doubtless was directly related to the development of a large number of anticyclones over the western Canadian provinces and their subsequent movement southeastward over the United States and likewise of the development and movement of a group of cyclones from British Columbia and the State of Washington southeastward to various points west of the Mississippi, thence northeastward to the Great Lakes and down the St. Lawrence Valley.

When cyclones recurve to the northeast east of the Mississippi generous precipitation is assured to Atlantic coast districts but cyclonic storms passing down the St. Lawrence Valley may or may not yield generous rains to the piedmont section of Atlantic seaboard States. In January, 1930, there was more or less failure of the rains from the Carolinas northward to New England; thus in a rather devious path we relate the failure of the rains in the beginning of the drought to the course and character of the cyclonic storms which passed across the country.

The change in pressure from January to February, 1930, was exceptionally large; whereas high pressure prevailed in January it gave way remarkably to low pressure in February and with the low pressure an unusually large crop of cyclonic storms most of which entered the conti-

nent north of 50° north latitude and moved eastward at or north of the Canadian boundary. As a result the warmest February, perhaps in a century, was experienced in the United States. With the exceptional heat there was much dryness and it is perhaps not far from the truth to ascribe the beginning of the drought to the disturbed condition of the general circulation that set in in that month. The succeeding months, March to June, were not especially dry except in rather small areas; North Dakota, for example had but 11 per cent of its normal rainfall in March. The most noticeable phenomenon was the breaking down of the cyclonic part of the secondary circulation and perhaps in one or two months the intensification of the circulation induced by anticyclones. The latter was especially noticeable in the piedmont sections of the States south of the Pennsylvania line. In these States it was doubtless the largest single factor contributing to the failure of the rains.

Anticyclones mostly from the Hudson Bay region drifted southward and settled over the Carolinas, Virginia, and Maryland thus insuring to those States at least a week of uninterrupted sunshine before the high pressure would pass away; moreover, the presence of high pressure over the Atlantic off the Carolina coast with the wedge-shaped front extending westward across the Appalachians doubtless diverted the paths of cyclonic storms approaching from the West into a more northerly course, thus withholding from the Virginia-Maryland region the rains that were received by States farther westward. Still another condition the reason for which is not known persisted, viz, cyclonic storms moving northward along and a short distant offshore failed to give rain in coastal States until the New Jersey coast was reached.

In September the weather control was mostly anticyclonic with no cyclones of importance, except, possibly on two occasions, the 23d and 26th; on the first named a cyclonic storm with circular isobars and central pressure down to 29.10 inches moved north-northeast from Montana to Manitoba with a further fall of pressure to 29.05 inches. A secondary from this cyclone developed over Colorado and moved thence to Wisconsin central pressure falling to 29.16 inches. This storm was attended by considerable precipitation in the Lake region and Ohio Valley, but the center of the cyclone continued to move northward to Hudson Bay in the ensuing 24 hours with no rain in the Carolinas and thence to southern New England. High pressure followed closely in the wake of the cyclone.

CONCLUSION

The secondary circulation, especially that branch which is associated with air movement about cyclonic systems, became weak and disorganized during the spring and early summer months of 1930. By midsummer a blanket of warm surface air had developed over the great interior valleys extending from the Gulf of Mexico to the Canadian border in which the normal temperature gradient with latitude had been destroyed.

Beginning with the turn of the season in September, when the transfer of polar air equatorward normally sets in, the chief weather control as between cyclones and anticyclones passed definitely to the anticyclones. In September, 1930, anticyclones from the Hudson Bay region moved south-southeast and merged with the semi-permanent high pressure over the Atlantic some distance east of the Carolina coast. In that position they served as a buffer to prevent cyclonic systems from moving up the Ohio Valley and spreading across the Appalachians into Atlantic coast States. The effect of this control was to augment the tendency of the dry weather to maintain the status quo in the piedmont sections of Atlantic coast States where drought still endures.

WEATHER CONDITIONS AS FACTORS IN THE FILTRATION OF THE WATER SUPPLY AT DETROIT, MICH.[1]

By BERT HUDGINS

[College of the City of Detroit, Detroit, Mich.]

Weather conditions are the most important single factor necessitating variations in the purification process in the Detroit water supply. Winds reaching from 20 to 30 miles per hour, for a few consecutive hours, tend to stir up the waters of shallow Lake St. Clair, lap the shores and gather pollution from them and their populous hinterland, with the result that at the filtration plant there is an increase in the turbidity, increased bacteria, and likewise increased *B. coli*. Thaws in winter cause ice to break loose from shores and streams to swell with polluted waters, bringing great quantities of sewage to the lake and water intake. Rainstorms flush out tributaries to Lake St. Clair, and in the spring, the break-up of ice in the upper Lakes produces much pollution. The intake for the water supply is located at the head of Belle Isle, near the outlet of Lake St. Clair. The area of Lake St. Clair is 460 square miles; no place in it is more than 22 feet deep, and therefore it is easily stirred up. Numerous tributaries drain to it from a populous land along its borders and the St. Clair River. The largest of these tributaries are Fox and Conners Creeks, entering a short distance above the intake. These creeks have given cause for great pollution in the past, but now their flow is intercepted and sent southward under Jefferson Avenue, paralleling the river, and making exit to the river some 4 miles below the intake. (Figs. 1 and 2.)

Evidences of the influences of the various conditions of weather can be seen best when charted with filtration records. The following study will show in the order named a case of the influence of the wind, the influence of wind when the lake is ice covered, the influences of wind and back flow of the river, rainstorms, thaws, and lastly a case of the influences of a combination of weather conditions on the filtration process.

Wind as a factor influencing filtration is illustrated by the storm of December 8, 1928. This storm developed from a well-marked LOW which passed eastward as most low-pressure areas do in the United States. This particular low passed slightly north of Michigan, and on the weather map of December 8, was centered about 200 miles north of Georgian Bay and was well-developed. A fairly well marked HIGH was located at the same time in Texas, and as is the case when well developed HIGHS and LOWS are so close to each other, the pressure gradient was steep (1.7 inches difference). The wind velocity reached a maximum of 60 miles per hour from the southwest at Detroit during the early morning of December 8. The direction shifted to the west for a few hours near midnight on December 8, but returned to the southwest,

[1] This article is an excerpt from a doctor of philosophy dissertation submitted at Clark University, Worcester, Mass. in April, 1930.

where it remained with a velocity of about 20 miles per hour until December 11. This high wind velocity lashed the river and lake waters into a billowy sea. The *Tashmoo*, Belle Isle ferryboat, was broken loose from its winter moorings near the foot of Woodward Avenue, and blown upstream 3 miles and lodged against the Belle Isle Bridge. The northeast-southwest trend of the river here facilitated the movement. The filtration plant recorded rapid rises in turbidity and bacteria almost immediately following the high wind. (See fig. 3.) *B. coli* counts rose to the unprecedented number of 100,000 per 100 cubic centimeters of sewage, and the application of alum was increased one-third for the five days beginning with December 7.[1] Since many sewers empty into the river a short distance from the intake, it is evident that much of this sewage, perhaps in the form of a greasy surface film reached the intake. When the cost of extra alum used as a result of this storm is calculated, it is found to amount to about $550. This expense does not consider extra chlorine, the shortening of the rate of filter run, and consequent increased cost of operation thereby, to say nothing of extra labor and worry of officials and laboratory men. The weather disturbance of December 8, considered as a 5-day storm as charted, cost the city $550 in alum alone.

Wind, when the lake is covered with ice, has little influence in the filtration process. If the ice cover is unbroken on Lake St. Clair it prevents wind contact with the water, and prevents increased turbidity and bacteria counts at the filtration plant. The windstorm of February 19, 1928, illustrates this fact. (Fig. 4.) Though a velocity of 35 miles per hour was reached and maintained above 20 miles per hour for 12 hours on the 19th, no increased pollution seems to be coincident with it. Weather records show that for nine days of the month of February preceding the 17th, there was a mean temperature of 32° F. or above, but that after February 19, the mean daily temperature was as low as 17° F. for several days. It is probable that these high preceding temperatures and resultant melting is a better explanation of bacteria and *B. coli* irregularities during this storm than increased wind velocity.[3]

Changes in air temperature and water "turnover" as factors in the bringing of turbidity, plankton, and pollution to the water supply are illustrated by the storm of November 29, 1928. (Fig. 5.) In it there is a close correlation of wind velocity and turbidity increases, as well as alum dose, bacteria, and *B. coli* on November 30 and December 1. However, the high *B. coli* shown on the early morning of November 30 is not explained thus, for no high wind velocity preceded it. It had not rained for one week previous, but the mean daily air temperature was 26° and 28° F., respectively, on November 25 and 26. By observing water temperatures it was noted that they fell to 39° F. on November 26, and except for December 16 and 17, remained below 39° until the end of the year. Since 39° F. is the temperature of the greatest density of water, it is likely that this is

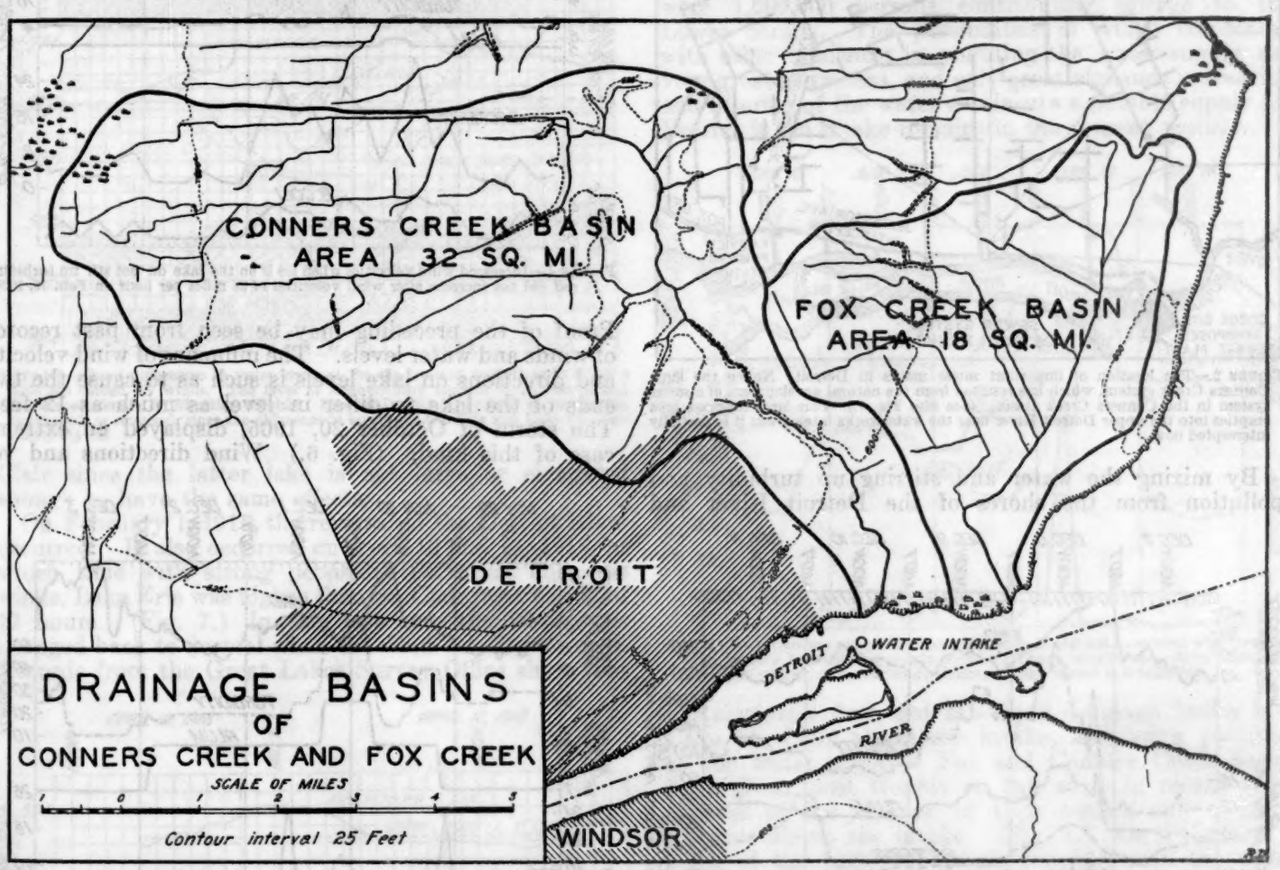


FIGURE 1.—The Fox Creek and Conners Creek Basins. Notice the nearness of the outlets of Fox and Conners Creeks to the water intake, Peche Isle, and the United States-Canadian international boundary

[1] Alum, aluminum sulphate, costs the city $1.25 per 100 pounds and is the largest single cost factor in filtration. A small carload is used daily (30,000 pounds).

[3] All weather data and filtration records are taken directly from the offices of filtration and the weather bureau in Detroit.

the water "turnover" period in Lake St. Clair, at which time it would naturally show an erratic record of bacteria because of the opportunity of these being brought from bottom to top, and exchanged about in this process. General plankton, bacteria, and *B. coli* increases come at this period of the year.

The back flow of the Detroit River is sometimes accomplished by winds, and the result is a difficult problem in the purification of the water supply at these times.

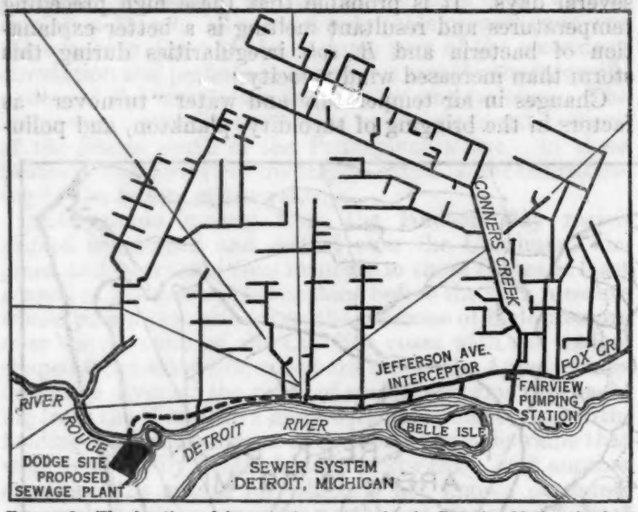


FIGURE 2.—The location of important sewer mains in Detroit. Notice the large Conners Creek system, which has resulted from the natural development of a sewer system in the Conners Creek Basin. (See also Fig. 1.) This large drainage area empties into the upper Detroit River near the waterworks intake, but it is partially intercepted now

By mixing the water and stirring up turbidity and pollution from the shores of the Detroit River and

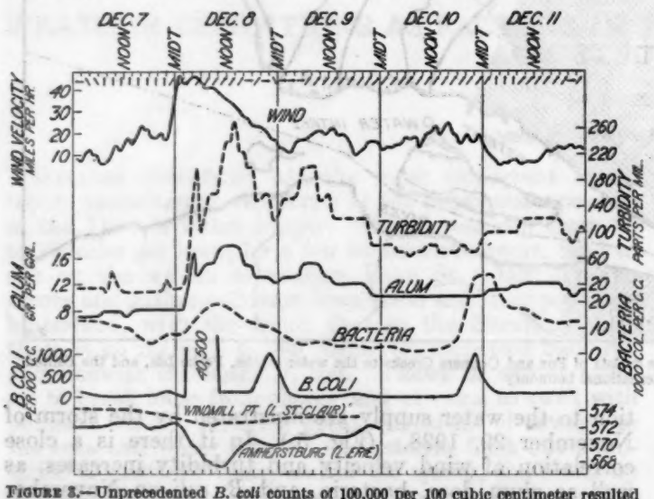


FIGURE 3.—Unprecedented *B. coli* counts of 100,000 per 100 cubic centimeter resulted from high wind velocities on Dec. 8, 1928. At midnight on the 7th, Lakes St. Clair and Erie were almost at equal levels. Increased alum was applied but turbidity did not serve as an indicator. In this case filter men realized from experience that high wind velocities would bring pollution, so additions of alum to facilitate coagulation and settlement, were made before contamination came

Lake St. Clair, and bringing this to the intake for the Detroit water system, the wind sometimes causes a back flow of the river which may give a great deal of impurity to the water at the location of the intake. Four conditions make this back flow possible: (1) Many sewers outlet into the river below Belle Isle Bridge; (2) the water intake is located at the head of the river and not far out into Lake St. Clair; (3) the average difference in elevation between Lake Erie and Lake St. Clair is 3½ feet, though they are 20 miles apart;[4] and (4) with strong enduring easterly winds, Lake Erie with its long east-west extent piles up water at its western end and thus checks the flow of the Detroit River, and raises the water level higher than that in Lake St. Clair.

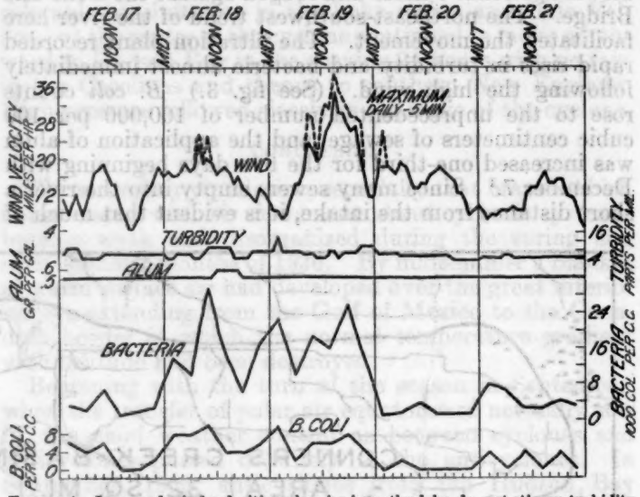


FIGURE 4.—Increased wind velocities when ice is on the lake do not stir up turbidity. *B. coli* did not increase after wind velocities of 38 miles per hour on Feb. 19, 1928

Proof of the preceding may be seen from past records of winds and water levels. The influence of wind velocity and directions on lake levels is such as to cause the two ends of the lake to differ in level as much as 12 feet. The storm of October 20, 1905, displayed an extreme case of this kind. (Fig. 6.) Wind directions and velocities are plotted by hours for Buffalo, Cleveland, Toledo, and Amherstburg. This shows a strong southwest wind with gale velocities in places recorded simultaneously for these cities, and lasting from 1 a. m. October 20, 1905, to midnight, but becoming west wind about noon at Toledo and sometime shortly afternoon at the others. As quickly as the winds had subsided somewhat, or changed from the southwesterly

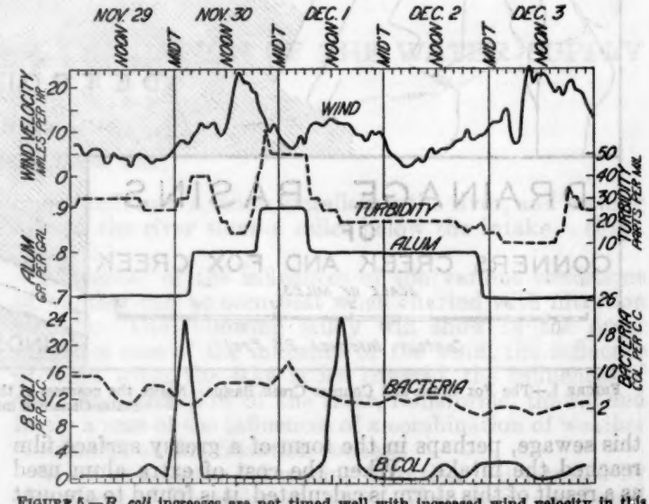


FIGURE 5.—*B. coli* increases are not timed well with increased wind velocity in this chart. It is possible that water "turnover" at this season of the year might bring a general disturbed condition of lake waters and thus explain *B. coli* increases on November 30 and December 1, 1928

[4] Windmill Point at the exit of Fox Creek on the American side of Lake St. Clair has a lake gage station. Amherstburg, Ontario, on the Canadian side and at the mouth of the river has a station at the level of Lake Erie.

direction, the difference in the water levels in the two ends of Lake Erie became less marked. This illustrates the influence of winds on water levels in the lake. Likewise when winds are strong from the east the condition is reversed. This latter situation is the one which builds up water elevations at the mouth of the Detroit River, checks its flow and causes "back flow" into Lake St.

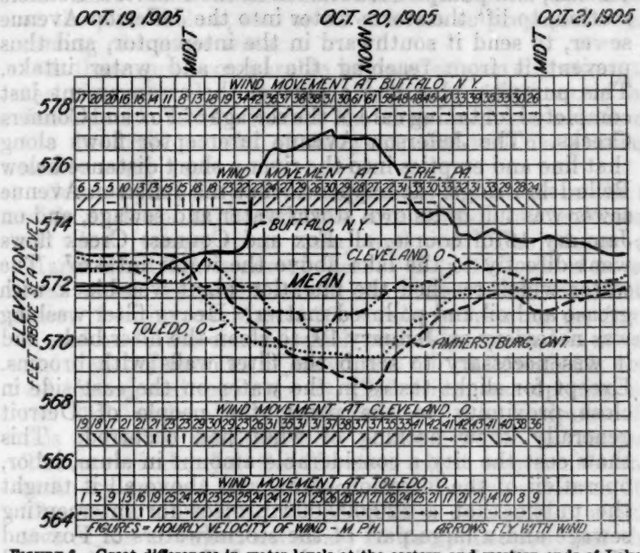


FIGURE 6.—Great differences in water levels at the eastern and western ends of Lake Erie are caused by winds. The level at Amherstburg (mouth of Detroit River) is watched closely by filtration officials. Flow of Detroit River may be slowed up, quickened, or reversed, since the difference in levels of Lake Erie and Lake St. Clair is only 3½ feet

Clair since the latter lake is not large or elongated enough to have the same effects.

On February 1, 1915, the reversal of the Detroit River occurred. It also occurred on April 10 and 11, 1918, at which time with strong persistent northeast and east winds, Lake Erie was higher than St. Clair for a period of 12 hours. (Fig. 7.) In this last case the lake levels changed back to normal when the wind velocity lowered. Records from the Great Lakes Survey Office show that

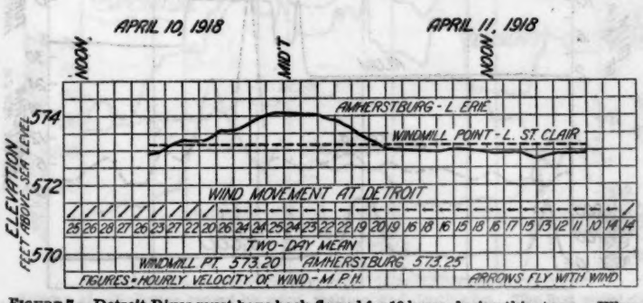


FIGURE 7.—Detroit River must have back-flowed for 10 hours during this storm. When the wind velocity decreased, Lake Erie fell. Notice that the level of Erie changes more than that of St. Clair

back flow must have occurred in the past on the following series of dates: February 5, 1909; February 6, 1911; March 21, 1913; January 31, 1914; February 1, 1915; April 10, 1918; and December 5, 1926. G. W. Hubbell, Detroit sanitary engineer, observed that on February 6, 1911, the back flow lasted more than seven hours, and that on this occasion there was a strong east wind, also ice in St. Clair River.[5] He believes that ice served to check the inflow, thus favoring back flow of the Detroit River. Back flow is likely to occur once in four years, according to Hubbell's estimate.

The results of back flow are not fully known. The whole question was first called to attention in 1916 by Hubbell and the international joint commission. No definite increases in typhoid have been associated with back flow, though several periods of intestinal disorders among the people have been attributed to the drinking water at these periods. Hubbell believes that sewage remains near the shore in back flow, as in regular downflow of the river, thus not reaching the water intake in great quantities. It is noted that the amount of sewage sent to the lake and river is increasing rapidly every year. The wastes of a population of approximately 800,000 people reached this outlet in 1918, while in 1930 there were 1,600,000 persons contributing sewage to the Lower Straits. The possibilities of winds combining with other influences in polluting the water supply are very great at present, and only great vigilance in treating and filtering of the water can insure a potable supply for Detroit if the intake remains in the present position.

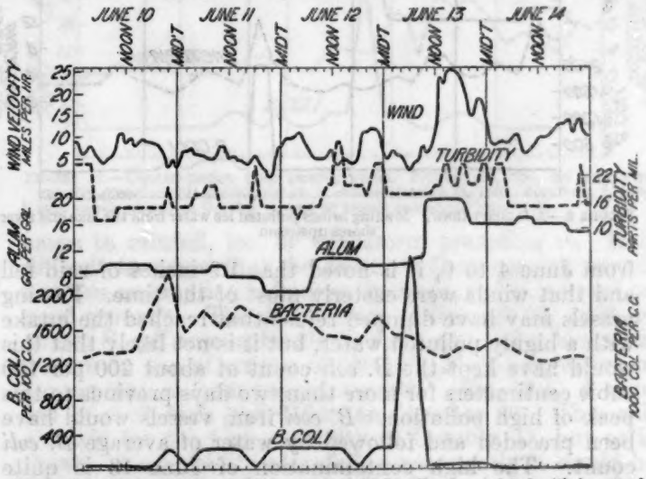


FIGURE 8.—A tremendous and sudden increase in *B. coli* not associated with increased wind velocity, but following closely a period of heavy rains for three days. A flushing out of polluted tributary streams to Lake St. Clair caused this pollution

Rainstorms flush out the small drainage basins into Lake St. Clair above the intake, and bring pollution to the water supply. Fox and Conners Creek basins have given most trouble on this score in recent years because of the location of their outlets only a short distance above the intake. (Fig. 1.) On February 1, 1926, of the 1,000,000 people supplied with the water from the municipal plant 200,000 had intestinal trouble. The Detroit Board of Health made a study of the situation and reported that it resulted from the pollution from the Conners Creek following heavy rains and melting. Weather records show no rain between the 28th and 30th of January, 0.04 inch fell on January 31, and 0.09 inch fell on February 1. There were 2 inches of snow on the ground and 10 inches of ice on the lake. On January 30 and 31 the maximum temperature was above 40° F. and the daily minimum was 2° above freezing.[6] With 0.13 inch of rain falling on frozen ground, and a melting snow and ice for two days, the situation preceding the intestinal trouble developed. Filtration records are incomplete for this period, and it is interesting to note that an additional chemist was employed immediately after.

[5] Hubbell, G. W., Report on Sewage of Detroit River, p. 16.

[6] Engineers Metcalf and Eddy estimate 0.03 inch of rain in 24 hours, sufficient to cause run-off from Fox and Conners Creeks.

The storm of June 10, 1928 shows a very high *B. coli* count immediately after heavy rains which flushed out tributary streams to the lake. (Fig. 8) *B. coli* rose past the 2,400 mark per 100 cubic centimeters on the morning of the 13th of June. Winds preceding this disturbance had been low. It is true that high wind velocities did occur in the afternoon of the 13th, but these could not have been a cause, for they followed the *B. coli* increase by 10 hours. The turbidity had been rather irregular on June 10, and 11, and 12. Looking back to the period

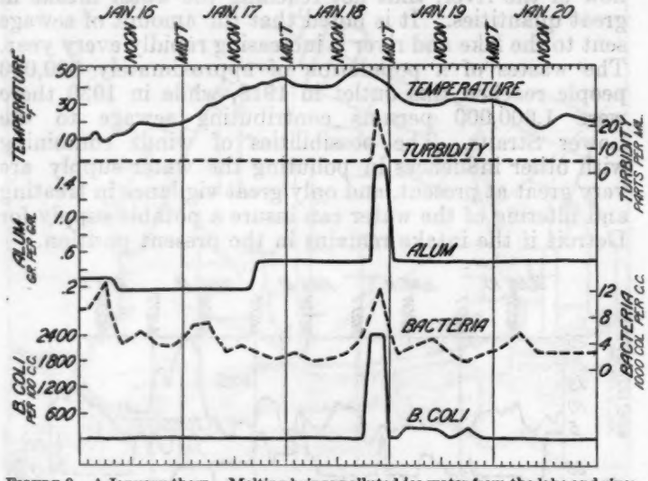


FIGURE 9.—A January thaw. Melting brings polluted ice water from the lake and river shores upstream

from June 4 to 9, it is noted that 1.9 inches of rain fell and that winds were easterly most of the time. Passing vessels may have dumped refuse that reached the intake with a highly polluted water, but it is not likely that this would have kept the *B. coli* count at about 200 per 100 cubic centimeters for more than two days previous to this peak of high pollution. *B. coli* from vessels would have been preceded and followed by water of average *B. coli* count. The high contamination of June 13 is quite clearly the result of flushing out of creeks—probably Conners and Fox—and the varying wind directions and velocities succeeded in bringing it to the intake near the head of Belle Isle. Winds from the south and southwest are more favorable for keeping sewage of Fox and Conners Creeks in the currents on the north shore of the river.

In considering the influences of rainstorms on the water supply, engineers have studied thoroughly the Fox Creek and Conners Creek areas. It was found that a rain of 0.03 inch would produce run-off, and that 96 run-off producing rains would occur in a year, on the average. Fox Creek is dry most of the year when Lake St. Clair stands at elevation 573.3 feet, as in 1926. The filtration plant must be prepared to treat excess pollution at any time, from such a possible source.

A good illustration of a thaw and its consequences in filtration of the water supply is seen in the weather and filtration data for January 16 to 20, 1929. (Fig. 9). For several days before January 16 the temperature had been low, and nothing unusual in the way of alum dose and *B. coli* is observed. Five inches of snow lay on the ground and there were 6 inches of ice on the lake. Beginning with 10° F. at 6 a. m. on June 16, the temperature rose steadily for two days, and reached 50° F. at 5 p. m. on the 18th. There was much melting and water ran everywhere. On January 18, there fell 0.87 inch of rain from midnight to midnight. The temperature dropped to freezing on the morning of the 19th, but practically all snow was gone by that time. Five inches of snow had melted; 0.87 inches of rainfall had run-off over frozen ground; much of the 6 inches of ice on the lake was gone; and ice was running freely in the river. At 9 p. m. on January 18, the turbidity, bacteria, and *B. coli* all rose simultaneously and the alum dose was trebled. The coming of trouble had been anticipated by filtration officials, and pumps were started at the Fairview-Conners station, to lift the storm water into the Jefferson Avenue sewer, to send it southward in the interceptor, and thus prevent it from reaching the lake and water intake. This pumping plan was a part of the arrangement just completed for taking care of the sewage of Fox and Conners Creeks. The Jefferson Avenue interceptor flows along that line and empties into the river a short distance below Belle Isle Bridge. It happened that the Jefferson Avenue sewer was full of its own storm water and sewage, and on January 18 of course, all Fox and Conners Creek flows went directly to the lake above the water intake.[1] The water which reached the filtration plant was black with grease and oil and polluted matter. Heavy filter washing was necessary on January 19, to clean the filter beds, and it was necessary to scrub the filter walls with brooms. Except for slight tastes in the water on the east side in close proximity to the plant, the people of Detroit generally knew nothing of what had occurred. This thaw cost the city a considerable amount in alum, labor, operation of the filtration plant, and above all it taught the public that a $20,000,000 project for intercepting sewage and a large part of the storm waters of Fox and Conners Creeks, to send it down Jefferson Avenue and out to the river at some lower point, must be rushed to completion.

Another thaw occurred on February 27, 1929. (Fig. 10.) It was similar to the one of the previous month just

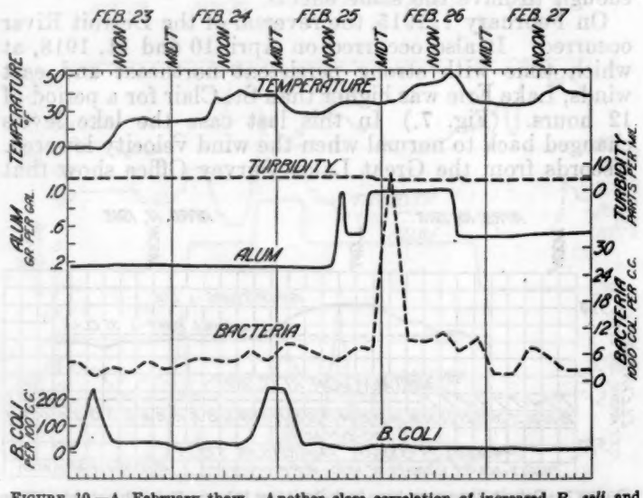


FIGURE 10.—A February thaw. Another close correlation of increased *B. coli* and increased temperature in winter

discussed. There were 4 inches of snow and 14 inches of ice on Lake St. Clair when it came, and 0.28 inch of rain fell to augment the difficulty. Without further detail concerning this thaw, the study of the chart shows that the line for turbidity indicated no change. It failed here to serve as an indicator of pollution for filter operators. Ice was on the lake and foul water beneath it quietly reached the intake without turbidity. The alum application was high on the 25th and 26th and remained fairly high for several days. As a result of

[1] Conversation with officials at filter plant, Jan. 20, 1929.

two thaws coming in two successive months to disturb the water supply, a plan was worked out by which it was required of operators of the diversion pumps at the Fairview station, to notify filtration officials when pumpage had reached the 6,000,000 gallon per day rate. This amount is the maximum for the pumps, therefore sewage and storm waters above that amount must go directly to the lake. Such notification would give filter operators at the plant below, two or three hours to prepare for the coming of impure water.

A thaw quite comparable in its effects on filtration, to the thaws of January and February, 1929, came on January 19, 1928. In fact the thaw is characteristic of the first two months of the year, and will likely occur nearly every year.

Some high pollution which reaches the water intake is without doubt explained by a combination of the factors of wind, temperature, rain, and ice. The storm of March 30, 1928, is one of these. (Fig. 11.) It is noted that water temperature and air temperature rose from below freezing on March 30, to above freezing on April 3, and made the change which probably resulted in much melting, the amount of snow that fell on March 30, was 4.8 inches, and ice in the St. Clair River was opening on the 28th and entirely open on the 4th. Undoubtedly this pollution resulted from a combination of causes. The use of alum at the filtration plant was double the ordinary amount for the three days beginning March 30. The excess alum is estimated to have cost $1,500, exclusive of the attention necessary in its application, and the related costs.

That the weather is the greatest physical factor influencing filtration is shown by the fact that winds stir up the water, thus increasing turbidity and pollution, and necessitating special and careful treatment. Temperature, likewise has its effect through winter thaws; rainfall in flushing pollution to Lake St. Clair and the river; and floating ice by bringing contamination from lake and river sources upstream.

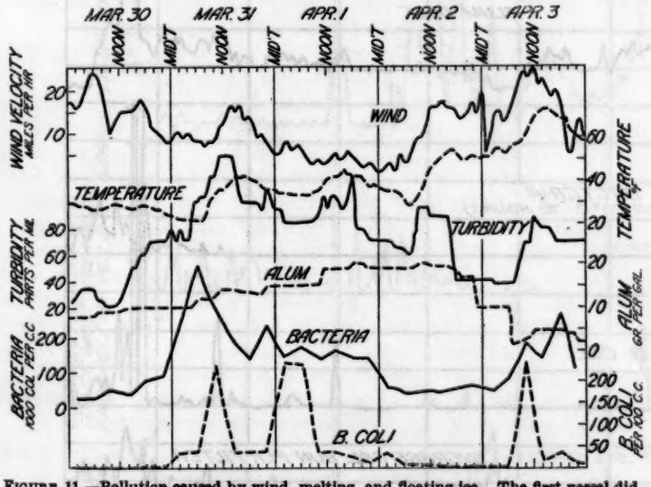


FIGURE 11.—Pollution caused by wind, melting, and floating ice. The first vessel did not go uplakes until April 3, and 4.8 inches of snow fell on March 30.

One other source of polluted water at the Detroit water intake is that from passing vessels. This may be associated with weather, since winds drive the oily and sewage materials, on the surface in the direction that the winds happen to be blowing at the particular time. However, the flow of water at the outlet of Lake St. Clair generally carries water from lake to river regardless of the direction of the wind. The ship channel at the head of Detroit River, follows the Canadian or south side of Belle Isle, and bends to pass on the north side of Peche Isle, keeping close to the international boundary. It passes on the upstream side and within 1 mile of the present intake for the Detroit water supply, and within about one-half mile of the proposed new intake and lagoon at the head of Belle Isle. (Fig. 1.) This nearness to ship channel has been a strong arguing point against the location of a water intake in the vicinity.

On a number of occasions the Detroit River supply has been very high in bacteria and *B. coli* without any evident

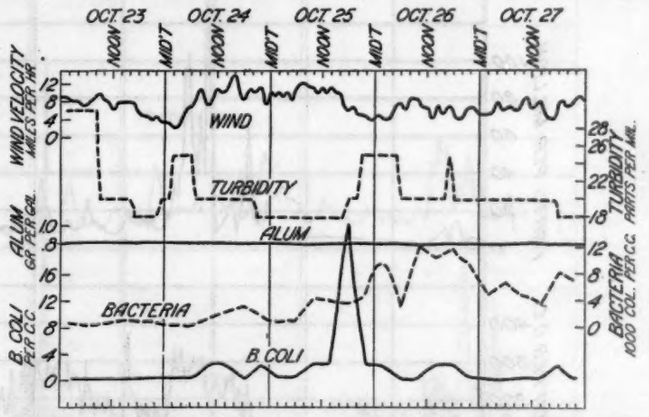


FIGURE 12.—Contamination from passing vessel. Neither ice, rain, nor high wind velocity preceded this sudden rise in *B. coli* on October 25, 1928. However, 77 large lake vessels passed on October 24, and 80 vessels passed on October 25

cause in rainfall, ice, or windstorm preceding it. It is difficult to prove that the source is from passing vessels but this assumption is frequently made, and it is based on good grounds. The disturbance of October 23, 1928, in which *B. coli* rose suddenly to 2,400 per 100 cubic centimeters on the afternoon of October 25, is suggestive of contamination from passing vessels. (Fig. 12.) A rainfall of 0.33 inch had fallen on October 22. This will account for the high turbidity of October 23, but as is shown, this turbidity soon fell, consequently it would be expected that *B. coli* would fall. The winds were of no consequence because the velocity never exceeded 14 miles per hour for three days preceding the coming of this polluted water. There was no ice, for the water temperatures were above 50° F., but records reveal that the vessel traffic was heavy on October 24 and 25, with 77 and 80, respectively. Though not conclusively proven, it is highly probable that pollution did come from passing vessels during these two days.

A summary of the influence of weather on filtration may be made by plotting the daily values of winds, temperature, precipitation, turbidity, plankton, bacteria, *B. coli*, and alum dose and the average daily gallon run per filter at the filtration plant for a year, coordinately, and noting the relations of the curves to each other. This has been done and appears in the chart form. (Figs. 13 and 14.) The wind velocities are shown to vary from a calm to a maximum of 60 miles per hour in 1927. Only the months of July and August show a tendency not to have a velocity of 30 miles per hour, at least once in the month in both 1927 and 1928. April and December have peaks of high velocities both years. The turbidity peaks of the year come in spring at the close of March and beginning of April, and again in the fall at the end of November. These turbidity peaks are closely associated with the temperature, 39° F. at which there is a general turnover of the waters of Lake St. Clair. Undoubtedly the high turbidity in spring is associated

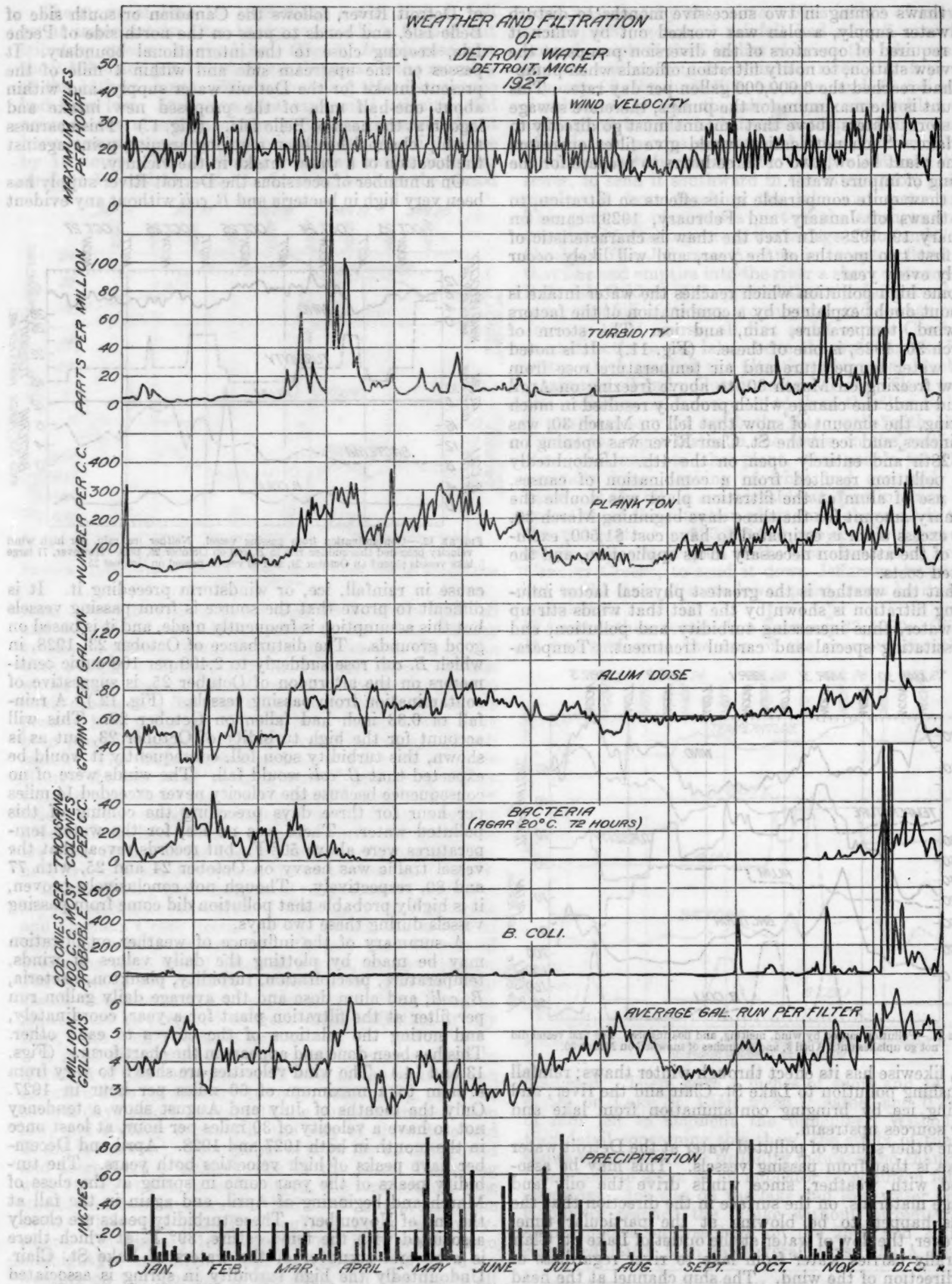


FIGURE 13.—Turbidity, plankton, bacteria, and alum increases come in spring with floating ice and water turnover and again in the late fall with water turnover and storms

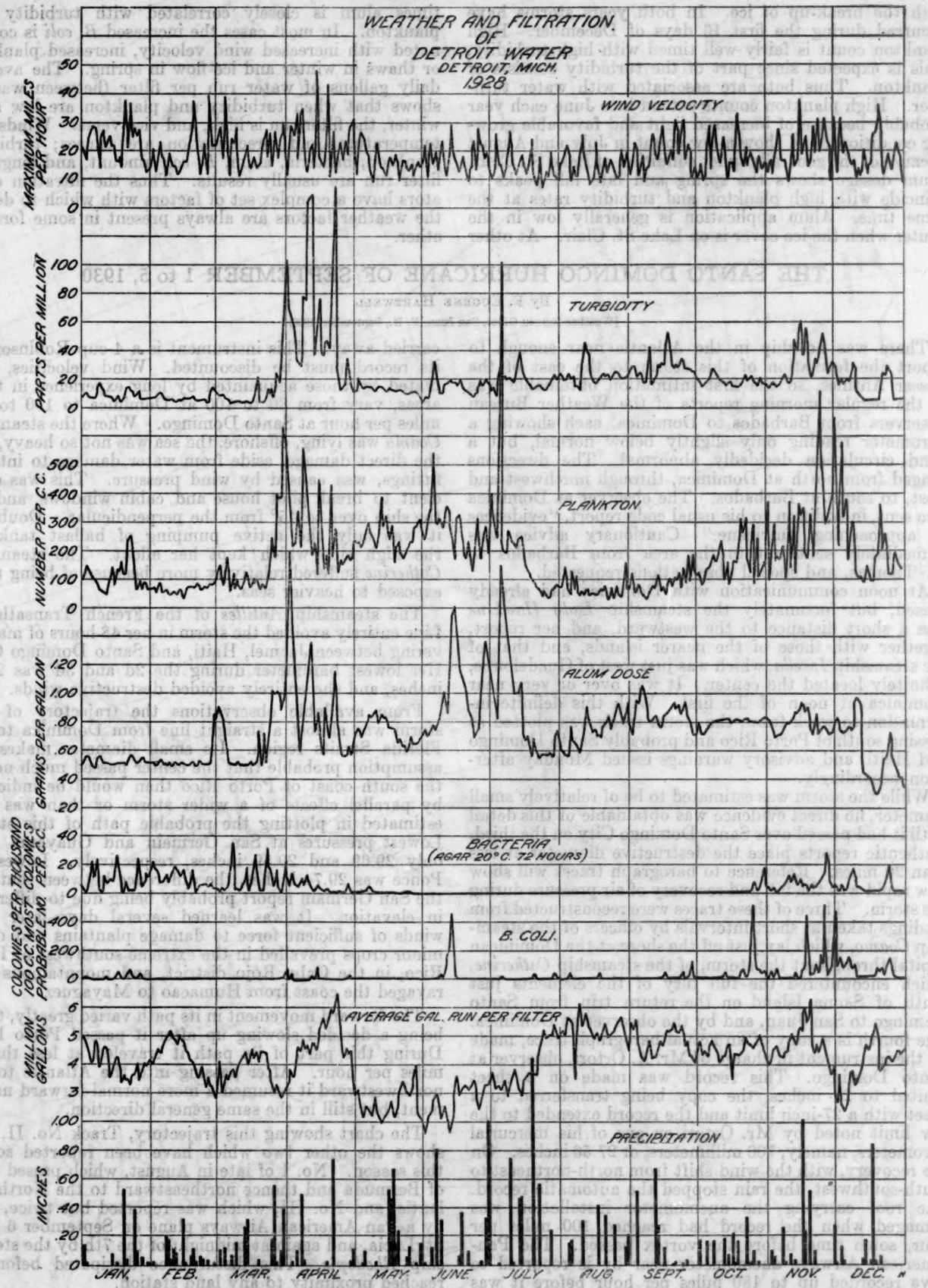


FIGURE 14.—Thaws and water turnover in both spring and fall are evidenced in this chart, as well as increased wind velocity and rainfall as causes for pollution

with the break-up of ice. In both years storms have occurred during the first 10 days of December. High plankton count is fairly well timed with high turbidity. This is expected since part of the turbidity consists of plankton. Thus both are associated with water turnover. High plankton counts extend into June each year probably because of increased light and favorable growing conditions, and show a low count in July and August because of the generally quiet condition of Lake St. Clair. Alum dosage shows the spring and late fall peaks to coincide with high plankton and turbidity rates at the same time. Alum application is generally low in the winter when the ice cover is on Lake St. Clair. At other times alum is closely correlated with turbidity and plankton. In most cases the increased *B. coli* is coordinated with increased wind velocity, increased plankton, or thaws in winter and ice flow in spring. The average daily gallons of water run per filter (between washes) shows that when turbidity and plankton are low as in winter, the filter run is high, and vice versa. Winds, ice, temperature, and precipitation are causes; turbidity, plankton, bacteria, alum, *B. coli* amount, and length of filter run are usually results. Thus the filtration operators have a complex set of factors with which to deal—the weather factors are always present in some form or other.

THE SANTO DOMINGO HURRICANE OF SEPTEMBER 1 to 5, 1930

By F. EUGENE HARTWELL

[Weather Bureau Office, San Juan, P. R., September, 1930]

There was no ship in the Atlantic near enough to report the formation of this storm to the east of the Lesser Antilles, so the first intimation obtainable was in the regular morning reports of the Weather Bureau observers from Barbados to Dominica, each showing a barometer reading only slightly below normal, but a wind circulation decidedly abnormal. The directions ranged from north at Dominica, through northwest and west, to south at Barbados. The observer at Dominica also sent, in addition to his usual code report, "evidences of approaching hurricane." Cautionary advice was immediately sent out to the area from Barbados to St. Thomas, and special observations requested.

At noon communication with Dominica had already ceased, but fortunately the steamship *Lady Hawkins* was a short distance to the westward, and her report, together with those of the nearer islands, and that of the steamship *Invella*, which was just west of Guadeloupe, definitely located the center. It was over or very near Dominica at noon of the first. With this definite information to work from, the storm track was plotted as passing south of Porto Rico and probably Santo Domingo and Haiti, and advisory warnings issued Monday afternoon accordingly.

While the storm was estimated to be of relatively small diameter, no direct evidence was obtainable of this detail until it had passed over Santo Domingo City on the third. Authentic reports place the destructive diameter at less than 20 miles. Reference to barograph traces will show how rapid was the fall and recovery of air pressure during the storm. Three of these traces were reconstructed from readings taken at short intervals by officers of the steamship *Coamo*, which lay just off the shore at the Dominican capital throughout the storm, of the steamship *Catherine*, which encountered the full fury of the elements just south of Saona Island on the return trip from Santo Domingo to San Juan, and by the observer at Dominica. The fourth is a copy of an actual barograph trace, made by the instrument in charge of Mr. A. Ortori, observer at Santo Domingo. This record was made on a sheet limited to 28 inches, the copy being transferred to a sheet with a 27-inch limit and the record extended to the low limit noted by Mr. Ortori on one of his mercurial barometers, namely, 700 millimeters, or 27.56 inches. On the recovery, with the wind shift from north-northeast to south-southwest, the rain stopped the automatic record. The roof carrying the anemometer installation was damaged when the record had reached 100 miles per hour, some time before the vortex passed. The Pan-American Airways anemometer near by is reported to have recorded up to 180 miles per hour before it was carried away. This instrument is a 4-cup Robinson, so its record must be discounted. Wind velocities, estimated by those acquainted by long experience in these areas, vary from 80 to 100 at Dominica to 150 to 200 miles per hour at Santo Domingo. Where the steamship *Coamo* was lying, offshore, the sea was not so heavy, and the direct damage, aside from water damage to interior fittings, was caused by wind pressure. This was sufficient to break pilot house and cabin windows, and list the ship over to 45° from the perpendicular. Doubtless it was only the active pumping of ballast tanks to the high side which kept her afloat. The steamship *Catherine* suffered relatively more because of being more exposed to heavier seas.

The steamship *Antilles* of the French Transatlantic Line entirely avoided the storm in her 48 hours of maneuvering between Jacmel, Haiti, and Santo Domingo City. Her lowest barometer during the 2d and 3d was 29.67 inches, and she entirely avoided destructive winds.

From available observations the trajectory of this storm was almost a straight line from Dominica to the Florida Straits region. Its small diameter makes the assumption probable that the center passed much nearer the south coast of Porto Rico than would be indicated by parallel effects of a wider storm or than was first estimated in plotting the probable path of this storm. Lowest pressures at San Germain and Guayama were only 29.69 and 29.59 inches, respectively. Lowest at Ponce was 29.74 inches, the difference between that and the San Germain report probably being due to difference in elevation. It was learned several days later that winds of sufficient force to damage plantains and other minor crops prevailed in the extreme southwest of Porto Rico, in the Cabo Rojo district, and mountainous seas ravaged the coast from Humacao to Mayaguez.

The forward movement in its path varied greatly, there being a decided slowing up after it passed Porto Rico. During this part of its path it traveled at less than 8 miles per hour. After passing into the Atlantic to the northwestward it resumed a more normal forward movement, but still in the same general direction.

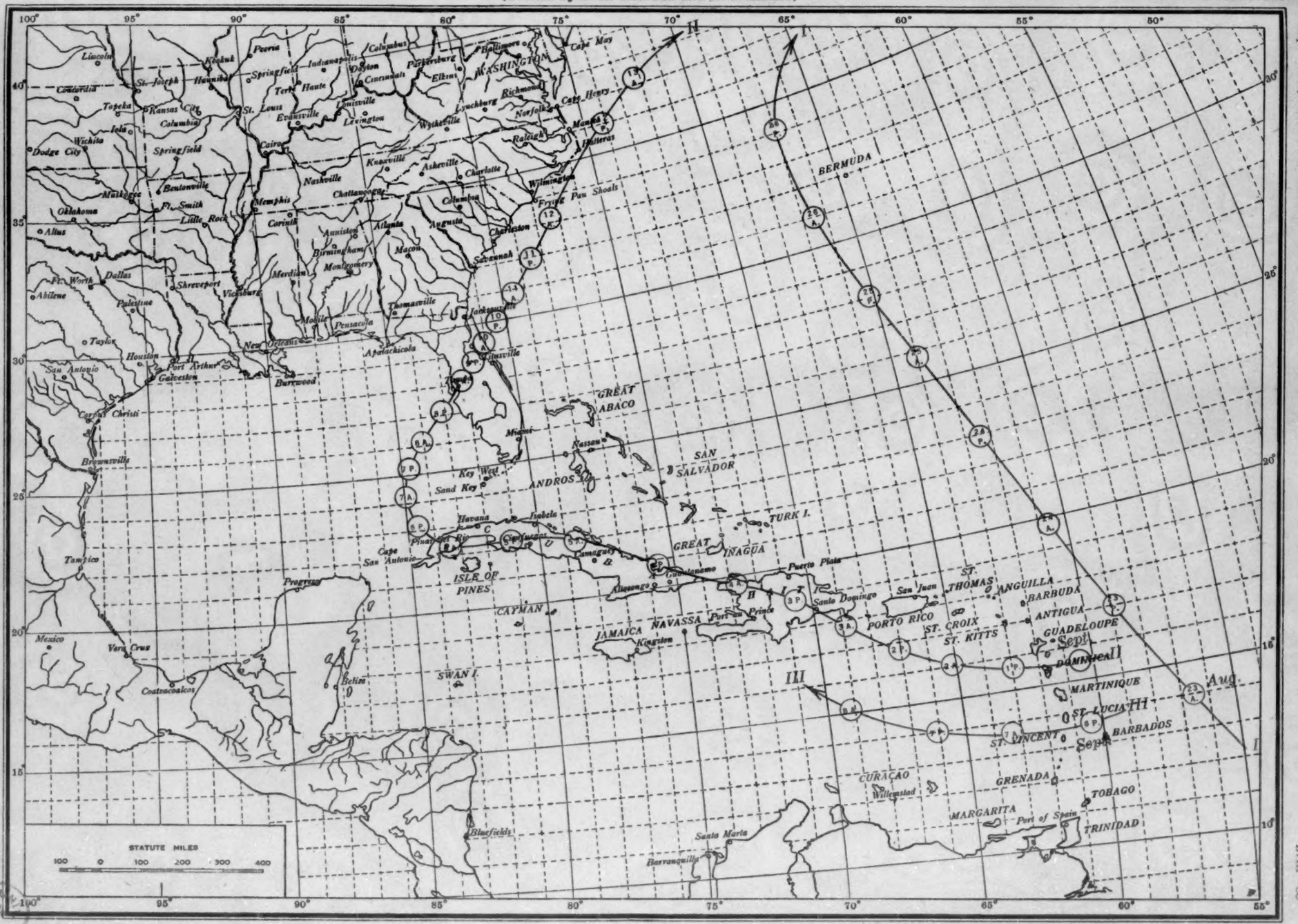
The chart showing this trajectory, Track No. II, also shows the other two which have been reported so far this season. No. I of late in August, which passed west of Bermuda and thence northeastward to the North Atlantic, and No. III, which was reported but twice, first by a Pan American Airways plane on September 6 near St. Lucia, and again at midnight of the 7th by the steamship *Rhodopis*. This disturbance dissipated before it reached proximity to any land station.

(To face p. 363)

Path of Santo Domingo Hurricane, September, 1930 (No. II). See text.
(Plotted by F. E. Hartwell and A. J. Haidle)

Path of Santo Domingo Hurricane, September, 1930 (No. II). See text.
(Plotted by F. E. Hartwell and A. J. Haidle)

(To face p. 362)



On the island of Haiti-Santo Domingo the damage was apparently negligible outside of the Dominican capital and its immediate environs. The surface friction over the mountain masses west of the city damped the storm to such an extent that beyond that point it was barely traceable, and it finally passed to the northeast over the Atlantic.

While the destructive effects of this storm in Santo Domingo, where 4,000 lives were lost[1] and property damage has been roughly estimated at $50,000,000, would class it as a major disaster, for Porto Rico it will be listed among the "beneficial" storms in that it caused much needed moderate to heavy rains throughout the island. The greatest amount reported was over 6 inches at Cabo Rojo; the least, strangely enough, was over the middle of the south coast, where it was under an inch. On the north coast it varied from somewhat less than an inch to more than 2 inches; in the interior from 1 to 4 inches.

APPENDIX I.—STORM CONDITIONS ENCOUNTERED BY THE STEAMSHIP "COAMO" SEPTEMBER 3, 1930

By BENJAMIN PARRY
[Western Bureau, New York City]

The steamship *Coamo*, flagship of the Porto Rico Line, is a vessel of 7,000 tons displacement. She plies between New York, San Juan, and Santo Domingo during the day of arrival, depending upon cargo requirements.

On September 1, the *Coamo* arrived at San Juan, but canceled her departure for Santo Domingo, due to advices that indicated a hurricane central off Dominica. The ship's barometer, 30 inches at 4 p. m., showed a downward trend during the night, and at 8 a. m., September 2, registered 29.87. Meanwhile the wind, which had been light east-southeast, backed to northeast, with moderate velocity. At 8 a. m., September 2, the following warning was issued by the San Juan office of the Weather Bureau:

> Center of storm is now apparently directly south of Porto Rico, about latitude 16° 13′, longitude 67° 00′, moving west-northwest. Storm will not touch Porto Rico. Advise caution next 12 hours for all shipping south of Santo Domingo and Haiti.

As the *Coamo* was now hours behind schedule it was decided to sail at 3 p. m. The ship departed with a light east-southeast wind which later backed to northeast, increasing, and a slowly falling barometer. At 11 p. m. the vessel was 5 miles south of Saona Island, steering west. She now encountered a moderate northeast gale and rough sea. As the vessel progressed and passed under the lee of the land the gale moderated and light rain began falling. By midnight the barometer had dropped to 29.68, with moderate northeast gale, and light rain continuing. At 4 a. m., September 3, the barometer ceased falling and the sky appeared to be clearing. During the next five hours the barometer gradually rose and at 9 a. m. stood at 29.72. The wind remained moderate north-northeast and sky continued to brighten. At 9:30 a. m. the *Coamo* was 5 miles southeast of the city of Santo Domingo. The harbor was too rough to venture for anchorage. The ship now cruised outside, headed east with engines slow ahead, awaiting further moderation of sea within the harbor. At 10 a. m. the pressure again started downward and a tremendously high following swell and rough northeast beam sea set in. The ship pitched and rolled heavily, shipping spray over hatches and decks. By 10:30 a whole gale from northeast was encountered with driving rain, making it necessary to sound fog signals continuously. During the next hour the pressure continued to fall and at 11:30 a. m. reached 29.45. The wind had attained a velocity of 125 miles per hour, and the ship became unmanageable. At noon the barometer registered 28.22, having fallen 1.23 inches in 30 minutes. The wind was now blowing 150 miles per hour which carried the rain and spray in sheets cutting the visibility to a few yards. Shortly after noon the wind velocity dropped rapidly and at 12:25 p. m. the ship was in a calm, with heavy confused sea pitching and seething, resembling a boiling cauldron. Hundreds of birds were seen flying about or resting on the ship. The barometer continued to drop, the indicator finally passed below the graduated scale and striking the attached thermometer was prevented from descending lower. The distance between the scale and thermometer corresponds to 0.10 inch, thereby indicating the lowest pressure as 27.70 (Captain Evans estimated the low point as 27.65). During this time the aneroid pumped violently, frequently rising 0.20 inch then returning to rest on the thermometer. At 1:04 p. m. the wind shifted to southwest with velocities quickly increasing until the gale raged as heavily as experienced before the center of the storm passed. At 1:25 p. m. a velocity of 150 miles was experienced, after which it gradually subsided, becoming moderate southerly at 8 p. m.

At the height of the storm rain and spray were driven in sheets hiding from view the foremast and rails. Glass was blown in, hatch covers, boat covers, and tarpaulins tossed into the sea, the radio antenna was carried away, skylights broken, and the interior of the ship drenched. The *Coamo* had but 92 tons of cargo aboard. The ship listed 20° and occasionally rolled to 40°.

Pressure readings recorded on the steamship "Coamo," September 1–3, 1930

Date	Time	Pressure	Date	Time	Pressure
		Inches			*Inches*
Sept. 1	3 p. m.	29.97	Sept. 3	4 a. m.	29.60
	4 p. m.	29.95		5 a. m.	29.60
	5 p. m.	29.94		6 a. m.	29.60
	5.30 p. m.	29.93		7 a. m.	29.64
	6 p. m.	29.94		8 a. m.	29.69
	7 p. m.	29.95		9 a. m.	29.72
	7.30 p. m.	29.94		10 a. m.	29.71
	8 p. m.	29.94		10.30 a. m.	29.66
	Midnight	29.92		10.35 a. m.	29.62
Sept. 2	6 a. m.	29.84		11 a. m.	29.53
	7 a. m.	29.86		11.20 a. m.	29.45
	8 a. m.	29.87		Noon	28.22
	9 a. m.	29.88		12.43 p. m.	28.18
	10 a. m.	29.90		12.45 p. m.	28.05
	11 a. m.	29.88		12.48 p. m.	27.85
	Noon	29.87		1 p. m.	27.78
	1 p. m.	29.85		1.01 p. m.	27.70
	2 p. m.	29.82		2 p. m.	28.30
	3 p. m.	29.80		2.30 p. m.	29.40
	4 p. m.	29.81		2.40 p. m.	29.50
	5 p. m.	29.80		3 p. m.	29.54
	6 p. m.	29.79		4 p. m.	29.60
	7 p. m.	29.80		5 p. m.	29.74
	8 p. m.	29.79		6 p. m.	29.79
	9 p. m.	29.76		7 p. m.	29.80
	10 p. m.	29.75		8 p. m.	29.86
	11 p. m.	29.71		9 p. m.	29.90
	Midnight	29.68		10 p. m.	29.91
Sept. 3	1 a. m.	29.67		11 p. m.	29.92
	2 a. m.	29.63		12 p. m.	29.94
	3 a. m.	29.62			

Pressure range from time of vessel's departure from San Juan to center of storm, 2.10 inches.
Pressure fell 0.08 in 1 minute, 1 p. m. to 1.01 p. m.; 0.20 in 3 minutes, 12.45 p. m. to 12.48 p. m; 1.23 in 40 minutes, 11.20 to noon.
Pressure increased 0.60 in 59 minutes, 1.01 p. m. to 2 p. m.

Captain Evans made a record of pressure readings which were read by Chief Officer Otto Berggren, as frequently as ship duties permitted. The ship's barometer was compared with standard at New York, July 16, and at San Juan, September 1, and found to be correct. On September 9, the instrument was 0.02 too high, comparison being made with portable aneroid.

[1] A more recent estimate made by an official of the American Red Cross places the loss of life at 2,000, the injured at 8,000, and the property loss at $15,000,000.—Ed.

APPENDIX II

C. L. MITCHELL

After leaving the northwestern corner of Haiti during the early night of the 4th, the tropical disturbance, which was now of minor intensity, crossed the Windward Passage and moved west-northwestward almost the entire length of Cuba, passing into the Gulf of Mexico during the 6th. No damage has been reported from Cuba. By the morning of the 7th, the disturbance had recurved toward the north and the next day toward the northeast, the center passing inland over Florida near Tampa about 4 a. m. of the 9th. The lowest barometer reading at that place was 29.70 inches with a maximum wind velocity of 36 miles per hour from the southeast.

During the next two days the disturbance moved very slowly northeastward over the Florida peninsula and into the Atlantic Ocean so that by the evening of the 11th its center was approximately 100 miles east of Jacksonville. No barometer reading as low as 29.80 had been reported since the center passed Tampa, and no strong winds, except that the steamship *J. Fletcher Farrell* which was east-southeast of the center during the afternoon of the 11th reported heavy squalls with wind from the southeast, reaching gale force at times. The morning reports of the 12th from land station and vessels showed that the center was some distance off the North Carolina coast south of Wilmington, but no strong winds and no pressure below 29.84 were reported. However, at 9.30 a. m. the steamship *Magmeric* off Frying Pan Shoals reported a pressure of 29.21 inches, and that it had fallen to 28.89 with a wind of force 12 at 8.30 a. m. As soon as this report was received, hurricane warnings were ordered hoisted immediately along the North Carolina coast from Southport to Beaufort, and southeast storm warnings north of Beaufort to the Virginia Capes. The center of the storm which was again of hurricane intensity eight days after passing over the city of Santo Domingo, approached close to the coast near Cape Lookout during the late afternoon of the 12th. However, little damage was done in this sparsely settled section. About a dozen small frame buildings were blow down at Cape Lookout and the Coast Guard headquarters building was damaged, while power and lighting systems at Beaufort and Morehead City were put out of commission for several hours and communication systems were disrupted.

By 8 p. m. of the 12th the center was passing east-northeastward to the south of Cape Hatteras where a maximum wind velocity of 60 miles per hour from the north was reported. During the next several days the disturbance moved almost directly eastward, the center passing a short distance north of Horta, Azores, on the 18th, after which the disturbance apparently merged with the severe storm that reached Ireland on the 19th. On the 15th the disturbance was still attended by winds of hurricane strength as shown by a report from the steamship *City of Agra*.

APPENDIX III.—ASSOCIATED PRESS DISPATCHES

AIRPLANE ENCOUNTERS SANTO DOMINGO HURRICANE

By GRETCHEN SMITH, Evening Star, September 11, 1930

Caught in the Santo Domingo hurricane, while flying from Porto Rico to Port au Prince, Haiti, en route from Brazil to the United States, Senhor Decio de Paulo Machado, representative from Brazil to the Pan American Conference, arrived in Washington last evening by plane specially chartered in Miami.

Senhor Machado left Rio de Janeiro about 10 days ago, having allowed himself ample time to arrive in Washington for the opening of the conference. On the hop between the Virgin Islands and Haiti, the Brazilian representative stopped at Porto Rico to lunch with Governor Roosevelt, a personal friend of many years. Senhor Machado related:

After leaving Porto Rico, I sat in front with the pilot of the plane, which was to make its next stop at Haiti. As I drowsed in my seat, I noticed directly before us a small black spot which seemed coming steadily toward us. As it approached it grew larger.

Not a breath of air was stirring and an ominous quiet seemed to weigh upon us. Suddenly, the wind began to blow and drops of rain like boiling water began to fall, rapidly becoming so violent that we were compelled to close all the windows of the plane.

The storm descended upon us so suddenly that before we knew it we were being swept along with the hurricane at a rate of 160 miles an hour. We were like a leaf in that storm.

When we had first seen the black spot approaching the pilot had remarked it was a storm coming and that he would 'beat it' by riding above it. That was impossible, as the storm had swept upon us before we had time to realize it. It was useless for the pilot to ride against it. He just allowed the plane to carry along with the storm at its will. We would be swept up into the air, and then dropped suddenly, as one might do when plunged into a body of water. At times I thought we would never come up from one of those drops.

However, we finally found ourselves above Santo Domingo Island, but everything was so dark and obscure, it was impossible to locate a place to land. After circling about for a short time, the pilot finally decided to land upon the water and take our chances of being rescued by sending wireless messages to shore. We landed safely, but after floating about for two or three hours, with no help from the land where we had sent messages we slowly taxied in toward the shore. We found ourselves at a small town, Barahona, on the coast about 15 miles from Santo Domingo City. No one in Barahona knew a thing about the hurricane. They laughed when we told them that a terrible storm had hit Santo Domingo. Barahona was untouched by the hurricane, and although telephonic and telegraphic communication to the capital were down, they merely thought they had been blown down by an ordinary storm.

The route of the storm was curious. It seemed to strike in spots. Certain parts of the country were terribly torn up, trees were uprooted and crops destroyed. Then directly next to a torn-up section the countryside was untouched.

RAINS SWELL OZAMA RIVER

PORT AU PRINCE, Haiti, September 8 (A. P.).—Heavy rains lasting more than 24 hours have swollen the Ozama River and made travel through the hurricane zone in the interior of Santo Domingo all but impossible to-day. The Ozama's flow has increased to 15 miles an hour, effectually preventing boats from entering its mouth.

Airplanes to-day formed virtually the only mode of travel into the area. Relief work went forward to-day as energetically as possible under such circumstances.

PATHETIC SURVIVORS WATCH SKY

The population pathetically watched the arrival of each plane at the Santo Domingo field, hailing each as angels of mercy alighting from the sky amid a scene of great misery.

Aviation reconnaissance has shown that the hurricane after razing Santo Domingo City traveled northwest, destroying everything in its path in an area 25 to 40 miles wide for a distance of about 50 miles.

When the hurricane hit the side of the mountains, rising almost perpendicularly in its path, the storm actually skinned the south slope of the mountain range there and hurtled into the air, touching only the high points in the succeeding ranges upon its course to the sea.

RICH VALLEY AREAS SPARED

The area of the Santiago, Vega, and Boca Valleys, which are the productive part of the country, were spared. The people of Santiago with whom observers talked related that they could hear the storm, howling like a million fiends in the air, as it passed overhead. The people were greatly awed by the phenomenon.

Plantations east of Santiago within the area of the storm were wiped out for a distance of 15 to 20 miles.—*Evening Star, September 8, 1930.*

FIGURE 1.—Shows some of the destruction in Santo Domingo. Hartwell

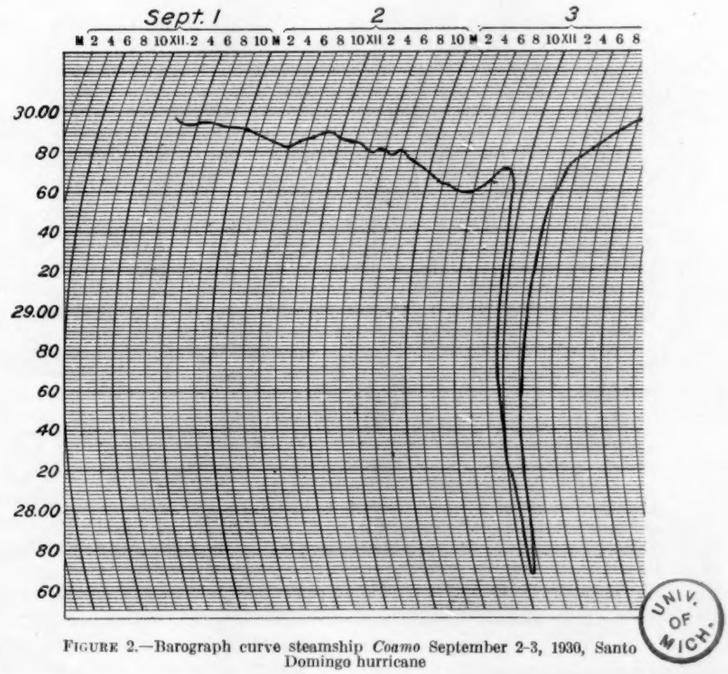


FIGURE 2.—Barograph curve steamship *Coamo* September 2-3, 1930, Santo Domingo hurricane

FIGURE 1.—Grove on outer edge of hailstorm, some damage

FIGURE 2.—Grove in center of hailstorm

HAILSTORM OF SEPTEMBER 7, 1930, ACROSS EXTREME SOUTHEASTERN SOUTH DAKOTA AND NORTHWESTERN IOWA

By GERSHOM K. GREENING
[Weather Bureau Office, Sioux City, Iowa]

On Sunday afternoon, September 7, 1930, one of the most destructive hailstorms of record for the middle Missouri Valley cut a swath 60 miles long and 5 miles wide across the extreme northern portion of Union County in South Dakota and extreme southwestern Sioux, central Plymouth, and north central Woodbury Counties in Iowa. (Fig. 3.) Although heavy rains were

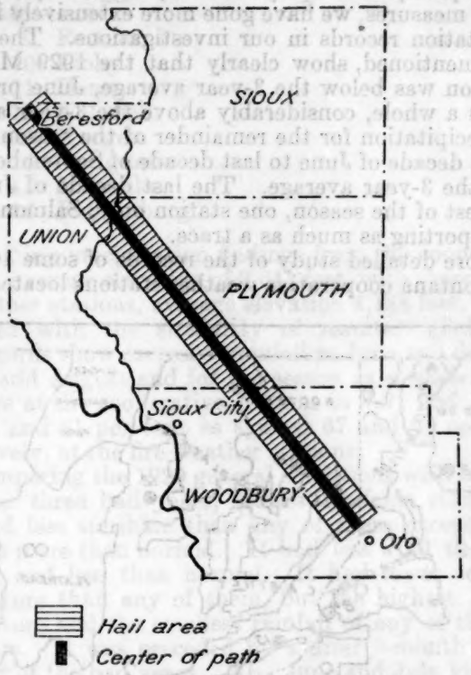


FIGURE 3.—Path of hailstorm, September 7, 1930

reported earlier in the day in line of the path of the storm projected to the northwest for 200 miles, the first hail was reported near Beresford, Union County, S. Dak., about noon. It was last observed at 3 p. m. 3 miles to the north of Oto, Woodbury County, Iowa. The path of greatest destruction as viewed by the writer ranged from a mile to a mile and one-half in width straight as "the crow flies" over the 60-mile stretch, although it is not intended to infer that the loss was constantly uniform. In some fields the damage would be as low as a bushel or two to the acre, while in others the corn would be a total loss. Cornfields that would have yielded 30 to 40 bushels to the acre were hammered to a barren waste. Others looked more like they had been "hogged down" for a couple of weeks. Large groves were left destitute of leaves and in the areas worst hit, "it looks just like January." Hailstones ranging in size from peas to walnuts and some say as large as baseballs covered the ground to more than an inch in places after the storm. The county is generally rolling and the hailstones were collected along the dry runs and small creeks that were filled to overflowing. Three or four days after the storm some hail had not entirely melted.

Eye witnesses are in agreement that the cloud was a heavy low black rolling formation with that peculiar greenish cast common to hailstorms.

One million dollars would be a conservative estimate of the damage done, most of which was to the corn crop. Poultry suffered heavily. Paint, roof, and window damage to buildings was likewise a big item of loss. Individual farmers reported as many as 200 chickens killed during the storm. The area swept was a heavy producing livestock section and cattle and horses exposed to the hail were literally covered with "bumps" for several days. Livestock must by instinct protect itself, as with the hailstones in the center of the path unusually large, no animals were found to have been blinded, although some small pigs were killed and there was also some loss to livestock from high water in connection with the storm. Telephone poles, fence posts, and farm buildings in numerous places were badly pelted by the stones as shown by the marks on the north and west exposures.

Twenty years ago hail insurance was little thought of in northwestern Iowa. To-day, it is carried on a large percentage of the farms and in many instances is required to protect the mortgage, rather than being due to the desire of the landowner or tenant to protect his own interests. Whether the hail insurance was taken as a result of foresight or compulsion, nevertheless quite a little of the loss will be retrieved from that source.

SOME 1929 FIRE-WEATHER COMPARISONS[1]

By E. M. KEYSER
[Weather Bureau office, Spokane, Wash.]

The season of 1929 holds a unique place in fire-weather history in United States district forest No. 1. This district comprises northeastern Washington, northern Idaho, Montana, and northwestern South Dakota. Since forest fire records have been tabulated, the last 22 years, the four seasons, 1910, 1919, 1926, and 1929 are outstanding. These four years account for 87 per cent of the fire losses in the district since 1907.

Howard Flint, in charge of fire-control measures in the district, furnishes the following summary of fires for these four bad years. He cautions that the figures, for comparison purposes, should not be taken too literally, because of the changing conditions from year to year.

Year	Number of fires	Area burned	Suppression cost
		Acres	
1910	1,736	2,400,000	$795,280
1919	2,258	1,329,000	2,157,515
1926	1,307	340,800	1,133,220
1929	1,949	241,500	1,697,500

In view of the small acreage burned in 1929, only about 10 per cent of that of 1910, and the relatively large number of actual fires and high suppression cost, about 80 per cent of that of 1919, when war time prices were still in vogue, it seems opportune to inquire into the nature of the season's weather phenomena and to ascertain, if

[1] Presented at a meeting of the Northwest Scientific Association on Dec. 27, 1929.

practicable, in what respects they have differed from normal conditions and from those of the other bad fire years.

In this investigation, we have gone into the records of some 18 fire-weather and 16 cooperative stations in northern Idaho and western Montana, where is located most of the district's timber and have also drawn heavily on the Spokane records, which are fairly typical of weather throughout the district, and much more complete; also to make the comparisons of wider application, the records

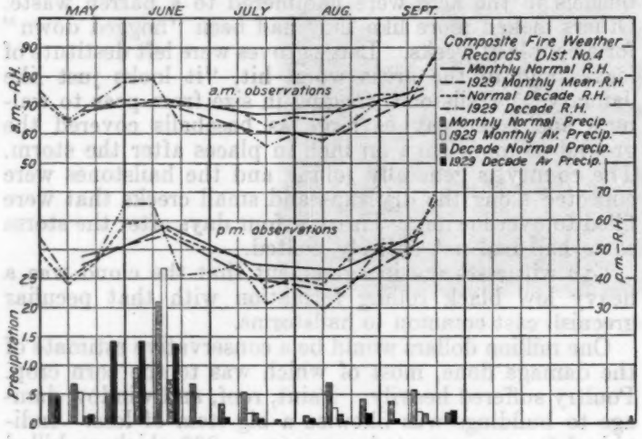


FIGURE 1

of other Weather Bureau offices in the Northwest and elsewhere have been consulted.

The Spokane records were used for sunshine and wind velocities. In Table 1, in comparing the bad fire years, we discover that 1929 for June, July, and August, averaged 79 per cent as against the 3-month normal of 76 per cent and the bad season average of 81 per cent. August, 1929, had *more* sunshine with its 94 per cent than any other summer month of the four bad years and June with its 59 per cent, *less* than any other of these months.

In Table 2, the wind velocities are seen to be below normal every month and below the bad season average. The August velocity of 4.8 miles was 16 per cent below the season normal and 20 per cent below the bad year average. The question arises, would this account for the unusual smokiness and increased difficulty of keeping in touch with the development and progress of going fires that month, which was an outstanding feature of the fire-control measures.

A glance at the temperature records, Table 3, reveals that in temperature, 1929 was not at all unusual. June averaged 1.5° below normal, August, 3.2° above normal, July being almost normal. The season itself ran 0.5° above the general normal and but 0.3° below the bad season average.

While Spokane normals were used for wind, sun, and temperature, the relative humidity and precipitation were measured at fire-weather stations and 3-year averages were computed. Mr. F. C. Crombie, fire-weather specialist, has kindly aided in this, going through the 1927, 1928, and 1929 records, computing means and then graphing both 8 a. m. and 5 p. m., relative humidity and rainfall, these being the hours at which readings were made.

A brief reference to the upper portion of graphs 1–8 (not reproduced) shows, in general, deficient humidity. However, at Avery and Savanac higher humidity is, unexpectedly, shown. But the Avery rise may possibly be accounted for by a more pronounced climb in humidity before the evening psychrometric readings were made. However, the Savanac plus readings are without adequate explanation. Composite graph (fig. 1) discloses that from May to the middle of the second decade in June the humidities were above the 3-year average and from then till the middle of the second decade in September they were below average. The maximum of the negative departure was at the end of the second decade in August. This also coincided with the increased fire-control difficulties.

Since precipitation plays such a prominent part in fire-control measures, we have gone more extensively into the precipitation records in our investigations. The graphs above-mentioned, show clearly that the 1929 May precipitation was below the 3-year average, June precipitation, as a whole, considerably above the 3-year average, and precipitation for the remainder of the season including last decade of June to last decade of September much below the 3-year average. The last decade of July was the driest of the season, one station only, Salmon Mountain, reporting as much as a trace.

A more detailed study of the records of some 16 Idaho and Montana cooperative weather stations located in the

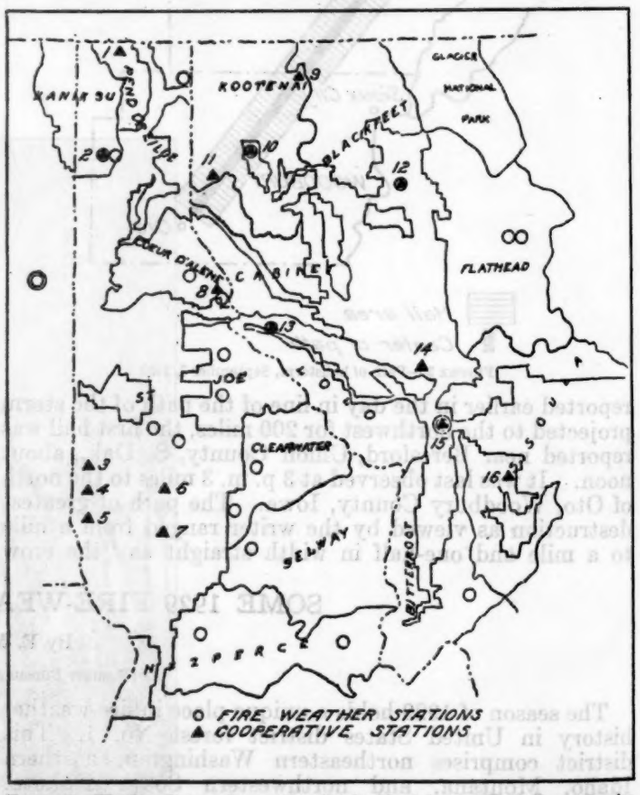


FIGURE 2.—Weather Bureau fire-weather district No. 4 (part of U. S. Forest Service district No. 1). The names of the stations corresponding to the numbers may be found in the text

principal timber sections of the district (fig. 2) permitted some interesting deductions (Table 4). It is seen that the 1929 fire season was preceded by an average of only 11.52 inches from September to May, inclusive, 36 per cent less than the normal average rainfall for these stations for the 9-month period. Then came the fire-season 3-month average of 2.70 inches, which was 28 per cent under normal notwithstanding June's precipitation was

112 per cent of normal. It will be seen that July and August had less than 25 per cent of the normal.

Cooperative stations furnishing meteorological data are as follows:

In Idaho:

1. Port Hill.
2. Priest River Experiment Station.
3. Pot Latch.
4. Moscow.
5. Lewiston.
6. Orofino.
7. Nezperce.
8. Kellogg.

In Montana:

9. Fortine.
10. Libby.
11. Heron.
12. Kalispell.
13. Haugen.
14. St. Ignatius.
15. Missoula.
16. Phillipsburg.

Comparing precipitation findings from the cooperative stations, average elevation of 2,641 feet, with those of the fire-weather stations, average elevation 4,188 feet, we are impressed with the similarity of results. (Table 5.) Both records show excessive rainfall in June and deficient in July and August and for the season as a whole. The shortages at the cooperative stations in July and August were 68 and 81 per cent as against 67 and 61 per cent, respectively, at the fire-weather stations.

In comparing the 1929 general conditions with those of the other three bad years, interesting facts stand out. 1929 had less sunshine than any of them except 1910, although more than normal. It had less wind than any of them and less than normal. It had lower seasonal temperature than any of them, but the highest August temperature and the smallest rainfall of any of the four bad years. It was preceded by a drier 9-month period than any of the bad years. Also June and July low temperatures and deficient sunshine tended to prolong the effects of June's heavy precipitation. But once the effects of this temporarily excessive moisture were overcome, the tendency of the preseason 9-month rain shortage was soon accentuated by the excessive August sunshine, high temperature, low wind, and general lack of rain. The conditions in individual forests can not be gone into here, but there existed in the latter part of July and the first two decades of August a widespread, dangerous condition, culminating in the unprecedented August conflagrations.

Apropos the theory that 1929's dry season is only another step in the general drying up of the Northwest, comparisons have been prepared showing annual precipitation by decades. Spokane has almost five complete decades of records. Her successive decade averages have gradually diminished. In 15 northern Idaho and western Montana stations the decade of 1911–1920 showed more precipitation than that of 1921–1930, to date or to end of 1930, considering 1930 a normal year.[2] Only two stations, Moscow and Sand Point, showed the reverse. For 1901–1910 and 1891–1900 decades, Port Hill, St. Maries, Libby, and Kalispell showed larger amounts in earlier decades. But Lewiston and Missoula records beginning in 1881 do not show such unbroken increase backward.

Furthermore, to get a more complete orientation in the matter of rainfall decline, we examined the decade averages of various well-distributed stations of long record all over the United States (Table 6). Nine decades of St. Paul, St. Louis, and New Orleans averages lend little argument to a general "drying up" theory. Neither do 8 San Francisco decades, 6 New York and Portland, nor 5 Los Angeles decades confirm a gradual dessication theory for any part of the country. It is true that a number of low 1921–1930 averages are discoverable, but this is true for St. Paul, St. Louis, Los Angeles, and San Francisco as well as our district No. 1 stations. Also, although not included in the table unprecendentedly low decade averages were found at Walla Walla, Boise, and Seattle in 1921–1930.

But we may conclude, that in spite of many 1929 dry spots in the Northwest and elsewhere and many last-decade low averages, any dessication tendency is not at all convincing.[3] The tables show that, in the past, low decade precipitation average has been followed by high decade averages. This is true in various parts of the country. As noted, not all northwestern stations have their lowest decade average in 1921–1930. The Northwest is a part of the great North American Continent and will share, as the decades accumulate, in the general distribution of the continent's rainfall. As the permanent and semipermanent HIGHS and LOWS to the west and northwest of us vary their migrations, water-laden clouds will be borne over the Northwest again and increasing precipitation will prevent many recurrences of the bad fire season of 1929.

TABLE 1.—*Percentage of sunshine at Spokane during bad fire-weather seasons*

Year	June		July		August		Season	
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
1910		75		88		74		78
1919	70	88	81	89	77	81	76	84
1926		78		92		75		82
1929		59		85		94		79
Summary								
Average for 3-month period								76
Average 4 bad seasons								81
Percentage for 1929								79

TABLE 2.—*Average wind velocities at Spokane during bad fire-weather seasons*

[Miles per hour]

Year	June		July		August		Season	
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
1910		7.4		6.4		5.7		6.5
1919	6.4	6.6	5.7	5.9	5.0	5.6	5.7	6.0
1926		5.8		6.1		5.4		5.8
1929		6.0		5.4		4.8		5.4
Summary								
Average for 3-month period								5.7
Average 4 bad seasons								6.0
Average for season of 1929								5.4

[2] It is impracticable as this goes to press to say whether 1930 in the far Northwest will or will not be a normal year.—*Ed.*

[3] See in this connection Henry, A. J., Weather Abnormalities in the United States (seventh note) trend of precipitation this REVIEW 58: 249–250.

TABLE 3.—*Mean temperature of bad fire seasons, district No. 1, from eight Idaho and eight Montana cooperative stations*

Year	June		July		August	
	Normal	Actual	Normal	Actual	Normal	Actual
1910		60.2		68.2		61.6
1919	59.2	59.4	65.8	67.1	64.4	65.1
1926		61.3		69.2		64.1
1929		57.5		65.7		67.6

SUMMARY

Fire season normal (June, July, August)	63.1
Bad season average	63.9
The 1929, 3-month average	63.6
1929 departure from normal	+.5
1929 departure from bad season average	−.3

TABLE 4.—*Average precipitation (inches) of bad fire seasons, district No. 1, from eight Idaho and eight Montana cooperative stations, average elevation, 2,641 feet*

Year	Precipitation for the preceding 9 months		June		July		August	
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
1910		17.42		0.74		0.24		0.42
1919	17.84	17.81	1.84	.33	0.98	.22	0.94	.96
1926		13.23		1.74		.49		2.29
1929		11.52		2.21		.81		.18

SUMMARY

Fire season normal (June, July, August)	3.76
Bad fire-season average	2.54
Total of 1929 monthly averages (June, July, August)	2.70
1929 departure from fire-season normal	−1.06
1929 departure from bad season average	+.16

TABLE 5.—*A comparison, June, July, and August, 1929, precipitation averages (inches) as obtained at 16 cooperative stations, average elevation 2,641 feet and those obtained at 18 fire-weather stations, average elevation, 4,188 feet*

Month	16 cooperative stations			18 fire-weather stations		
	Normal	Actual	Departure	Normal	Actual	Departure
June	1.84	2.21	+0.37	2.10	2.69	+0.59
July	.98	.31	−.67	.54	.18	−.36
August	.94	.18	−.76	.70	.27	−.43
The season	3.76	2.70	−1.06	3.34	3.14	−.20

TABLE 6.—*Precipitation averages by decades Weather Bureau stations outside district No. 1*

Decades	Spokane	St. Paul	St. Louis	New York	New Orleans	Los Angeles	San Francisco	Portland
1841–1850		14.49	45.34		53.64			
1851–1860		12.06	45.73		51.46		22.22	
1861–1870		14.80	40.76				24.89	
1871–1880		16.63	37.13	42.81	65.47		24.32	53.19
1881–1890	18.46	12.49	39.85	48.06	60.18	18.74	24.60	45.75
1891–1900	18.28	13.78	36.12	42.45	48.40	12.03	19.51	39.16
1901–1910	16.14	15.58	36.52	43.48	55.89	15.39	20.72	41.02
1911–1920	14.03	14.96	37.93	40.01	63.02	15.20	20.82	39.57
1921–1930	13.79	12.72	38.33	41.32	63.16	12.82	20.72	37.38

(Stations outside the State of Washington have a basis of less than 9 years in the last decade. The Spokane value, on the basis of normal precipitation in 1930). At this writing, October 17, 1930, it would seem as if 1930 will be a year of less than normal precipitation.

DISASTROUS FIRE WEATHER OF SEPTEMBER, 1929

By CHARLES I. DAGUE, FIRE WEATHER SERVICE

[Weather Bureau Office, Portland, Oreg.]

The outstanding features of the fire-weather season for 1929 were its extreme dryness, its length, and the heavy fire losses in September, and subsequently thereto, west of the Cascades in Oregon and Washington. It was by far the most severe and most strenuous season within the history of organized forest-fire protection in these two States, and probably for as far back as we have any record or knowledge of forest fires for these sections. There have been seasons with heavier fire losses, but they were before the time of organized protection. The extreme southwestern portion of Oregon and of northwestern California sustained their heaviest forest fire losses for the season during the last decade in November and the first week in December.

The worst drought in the history of Weather Bureau records prevailed from June 20 to December 7, not only in Oregon and Washington, but in all the far Western States as well. November was the fifth successive month with deficient precipitation, the average for the five months in Oregon, June to November, being 1.81 inches which is only 20 per cent of the normal; precipitation at the regular Weather Bureau stations in the far Western States averaged only 27 per cent of the normal for this 5-month period. It is also interesting to note in this connection that the average precipitation for November in Oregon was only 8 per cent of the normal, the normal for 94 stations being 4.52 inches. Of the 19 months ending with November, 1929, 17 months were drier than normal, with the total precipitation for this 19-month period in Oregon being only 62 per cent of the normal. Thus both the years of 1928 and 1929 were very dry, being climaxed by one of the worst droughts of record in the far West as well as by far the most critical fire weather conditions known.

Maj. Edward H. Bowie, district forecaster at San Francisco, Calif., in his paper on the Long Dry Season of 1929 in the Far West, published in the MONTHLY WEATHER REVIEW for November, 1929, very aptly explained the anomalies that caused the dry weather for the normally dry months of July and August to continue on through September, October, November, and the first week in December. These anomalies were due to the continuation through September and October of high or relatively high barometric pressure over the North Pacific Ocean in latitudes where ordinarily found only in the summer seasons, and of extraordinarily high barometric pressure in November in general along and off the West Coast, over the Plateau Region and western Canada. The cyclones of the North Pacific Ocean were unable to penetrate these high barometric pressures and their systems of winds, and were forced to move instead, along the northern periphery of the high pressure area in high latitudes. It was not until the barometric pressure rose in high latitudes, notably the Bering Sea and western Alaska, and decreased over the northeast Pacific Ocean, and northerly winds gave way to southerly and westerly, at the beginning of the second week in December, that the long dry season came to an end.

The fire-weather season for 1929 in Oregon was somewhat below normal up to the forepart of September, with

both the fire losses and expenditures slightly less than usual. But September 3 ushered in the most hazardous fire weather experienced in years, continuing almost without interruption until September 16, a 2-week period. During this period, many of the existing fires jumped the fire lines and new ones that started were immediately whipped out of control, so that within a short time, protective organizations in several of the units were taxed beyond their capacity. This was not only the darkest period in the 1929 fire-weather season, but also in the history of organized forest fire protection.

The worst fire-weather situations west of the Cascades always come with the advent of the dreaded east wind, attended in summer time by high temperatures and low relative humidities. When the relative humidity drops to 35 per cent, and lower, west of the Cascades, and even to 50 per cent, and lower, near the coast, fire-weather conditions become critical, and protective organizations must keep constantly on the alert as long as the relative humidity remains low. Low relative humidities of 20 per cent, and lower, east of the Cascades create a bad fire-weather situation too, but it is probable that wind force is of equal importance with low relative humidity for these sections in the creation of bad fire-weather situations.

Relative humidities were very low from the summit of the Cascades all the way to the coast during those dark days of September. And winds, at time of gale force, were prevailing from the east. The prevailingly low relative humidities of this 2-week period came in three surges, respectively, on September 3 to 4, 6 to 11, and 15 to 16, coincident with decided increases of barometric pressure over the interior to the northeast and decreasing pressure near the middle Pacific coast. Fire-weather conditions were at their worst from the 6th to the 11th, when very low relative humidities prevailed, being extremely low, from 15 to 30 per cent, on the coast on the 6th, 7th, and 8th. What made burning conditions even worse for this period was that there was scarcely any of the normal recovery of relative humidity at night over the west slope of the Cascades, and the higher elevations of the coast range, the only recovery of importance at night being at the lower elevations of the coast range. Wind force at the higher elevations of the mountains is usually greater at night than in the daytime; wind records at several lookout points in the Cascades and the coast range also showed higher wind velocities at night for this 2-week period. Thus going fires burned as well at night as during the daytime at these higher elevations, sometimes better. The severity of the fire-weather conditions that persisted during this period for northwestern and central western Oregon is presented on the accompanying map of western Oregon, graphically showing the number of hours with relative humidity of 35 per cent, and lower, at all stations equipped with hygrothermographs:

This map shows that fire-weather conditions were most critical along the central-west slope of the Cascades at elevations ranging from 3,000 to 4,000 feet, thence northwestward to the northwestern portion of the State. At one logging camp in eastern Marion County, at an elevation of approximately 3,200 feet, the relative humidity was 35 per cent, and lower, for 283 hours during this 2-week period. Further, the relative humidity at this camp was 35 per cent, and lower, for 133 consecutive hours, and 30 per cent, and lower, for 88 consecutive hours; from 8 a. m. of the 6th to 3 a. m. of the 17th, an 11-day period, the relative humidity was 35 per cent, and lower, for 240 hours, while the highest relative humidity for this time was only 49 per cent. The relative humidity records at a lookout and at a fire warden's headquarters in adjoining sectors were analogous to those at the camp. Similar relative humidity conditions were also recorded at many of the other stations equipped with hydrothermographs on the west slope of the Cascades in both Oregon and Washington, although not so extreme as on the central-west slope of the Cascades in Oregon.

The area burned over in Oregon in 1929 totaled 312,255 acres. The total monetary loss was $2,311,627. Fire losses and expenditures had been below normal over the State up to September 6. Over 90 per cent of the fire losses occurred subsequent to September 6, and about 90 per cent of the money spent in fire suppression was on

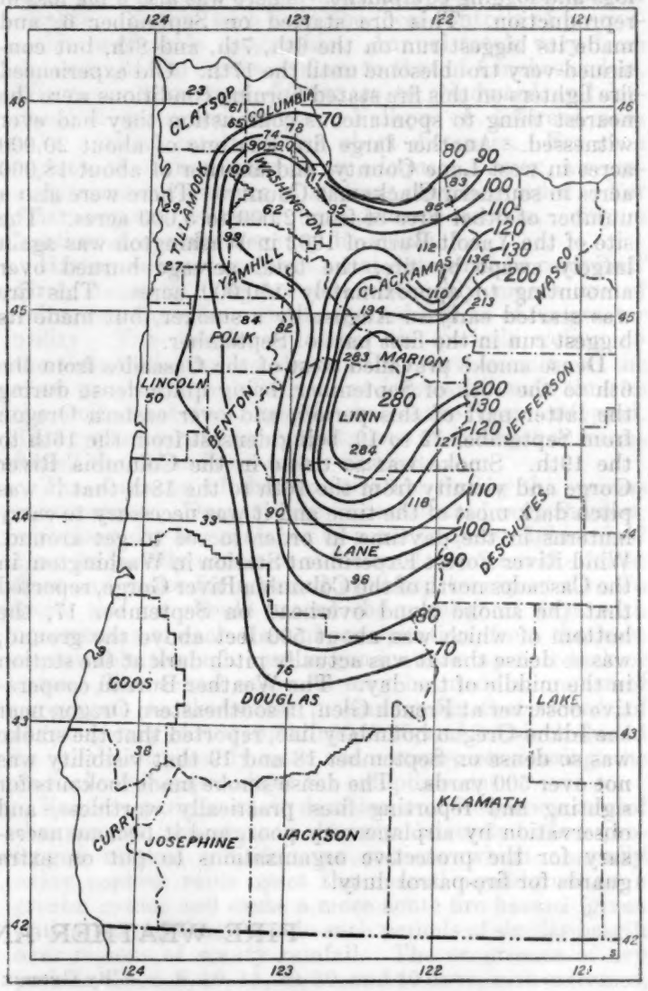


FIGURE 1.—Critical fire-weather in western Oregon as shown by the large number of hours with a minimum humidity of 35 per cent or less

fires subsequent to that time. At the end of August the Umpqua National Forest on the western slope of the southern Cascades had had only 13 fires, which had burned over a total area of only 1 acre, with fire-suppression costs of only $478; at the end of September 28 fires were reported for the season which had burned over 5,260 acres, and fire-suppression costs had mounted to approximately $50,000. The larger portion of the big increase for fires suppression and the big acreage burned over were incurred in the first two decades of September. The Douglas County Fire Patrol Association, adjoining the Umpqua National Forest on the west, reported that it had spent only about $500 for fire suppression to the end of August, but that over $20,000 had been spent by the

end of September. Fire-suppression costs and losses of a majority of all the other protective organizations west of the Cascades also took a decided upward trend in the first two decades of September, and on into the month of October for a few of these organizations. And it was necessary for some of the protective organizations to maintain patrol forces in the field until the first week in December, the first time in the history of organized protection.

The largest fire in Oregon occurred in eastern Marion County, and burned over approximately 46,000 acres with an estimated loss of $400,000, the greatest loss being in logs and logging equipment. There was also a big loss in reproduction. This fire started on September 6, and made its biggest run on the 6th, 7th, and 8th, but continued very troublesome until the 17th. Old experienced fire fighters on this fire stated burning conditions were the nearest thing to spontaneous combustion they had ever witnessed. Another large fire was one of about 20,000 acres in west Lane County, and another of about 18,000 acres in southern Clackamas County. There were also a number of other fires of from 2,000 to 5,000 acres. The site of the Yacolt Burn of 1902 in Washington was again largely swept by fire, the total acreage burned over amounting to approximately 150,000 acres. This fire was started early in August by a smoker, but made its biggest run in the first part of September.

Dense smoke prevailed west of the Cascades from the 6th to the 19th of September, being quite dense during the latter part of this period, and over eastern Oregon from September 12 to 19, being densest from the 16th to the 19th. Smoke was so dense in the Columbia River Gorge and vicinity from the 16th to the 18th that it was pitch dark most of the time and it was necessary to carry lanterns in the daytime in order to see to get around. Wind River Forest Experiment Station in Washington, in the Cascades north of the Columbia River Gorge, reported that the smoke cloud overhead on September 17, the bottom of which was about 500 feet above the ground, was so dense that it was actually pitch dark at the station in the middle of the day. The Weather Bureau cooperative observer at French Glen, in southeastern Oregon near the Idaho-Oregon boundary line, reported that the smoke was so dense on September 18 and 19 that visibility was not over 500 yards. The dense smoke made lookouts for sighting and reporting fires practically worthless, and observation by airplane very poor, and it became necessary for the protective organizations to put on extra guards for fire-patrol duty.

Special fire-weather warnings were telegraphed daily to the protective organizations of western Oregon from September 1 to 19, and again for several days at the end of the month. Many long-distance telephone calls were also received from those forestry interests desiring special information relative to fire-weather conditions.

There were recurrent periods of bad fire weather in October, November, and the first week in December, when burning conditions were good and gave the protective organizations and logging operators much concern.

Protective organizations in the Siskiyous and southern Coast Range sustained their heaviest fire losses of the season during the latter part of November and the first week in December. It was the first time in history that destructive fires have occurred so late in the season. The largest of these fires was the Barklow Mountain fire, which started the day before Thanksgiving and burned over more than 10,000 acres. Thanskgiving Day and night and the following day were bad fire-weather days, and were the days on which this fire and other fires made their biggest runs. Protection men reported that stiff east and northeast winds came in in a whirl, and that cold nights with dense fog prevailed in the lower valleys and levels while warm clear weather with relatively high temperatures and low relative humidities prevailed at the higher elevations. The barometric pressure was extraordinarily high at this time over the Plateau Region and western Canada.

The fire-weather season of 1929, within the history of Weather Bureau records, was undoubtedly the worst that has ever occurred in the Pacific Northwest, at least since 1868 when heavy fire losses occurred. According to the precipitation records at Astoria, Oreg., August and September of 1868 were very dry months, and it is well known that extremely heavy fire losses occurred in September, so extremely bad fire-weather conditions must have prevailed at that time. Fire-weather conditions for September of 1902 were bad and severe fire losses were sustained, but available weather records, while indicating serious fire-weather conditions for the most of one week, nevertheless, do not indicate that these conditions were as bad as for September for 1929. The extremely hazardous fire-weather conditions which prevailed during the latter part of the season for 1929 will long be remembered by the forest-fire protective organizations of Oregon and of all the Pacific Northwest as well.

FIRE WEATHER AND FIRE CLIMATE

By GEORGE W. ALEXANDER

[Weather Bureau Office, Seattle, Wash.]

Climatological data, for all portions of the earth's surface for which records of the weather elements are made, have become well standardized. Comparisons of the principal elements of the climate—temperatures, their means and extremes, and precipitation, its character, seasonal distribution and variability—are readily possible. Such comparisons are only possible, however, from the fact that there is uniformity of treatment of data, nationally and internationally, and the need for such uniformity is obvious. There is now a newly born, but rapidly developing, branch of meteorology and climatology for which no such uniformity of method of compilation of essential facts has been developed. Reference is made to the now rather widely spread studies of those phenomena known as "fire weather." While fire-weather data are being accumulated in increasingly large amounts, especially in parts of North America, there has as yet been no standardization of the ultimate treatment of such facts, so that a "fire climatology" may be established which will allow of comparison of the basic elements of the natural fire hazard over different regions as readily as a comparison of the general climate may be made at present. That there should be some such standardization would seem obvious enough. It is desired to set forth in the following paragraphs a tentative scheme, or suggestions, for a comprehensive fire climatology, which may form a basis for discussion, at least, and may ultimately, even if largely modified in accordance with the views of

others, lead to the adoption of standard methods in the several districts in which fire-weather studies are being made.

As a preliminary to the statement of manner of compilation of data some short discussion of the elements of fire weather, and the manner of securing fire-weather data should be pertinent. The weather elements generally accepted as affecting the degree of the fire hazard on forested, reforesting, cut-over and water-shed lands, with which we are chiefly concerned, are:

1. Precipitation, its amount, distribution, and variability.
2. Relative humidity, normals and extremes, with the frequency and persistence of critical percentages.
3. Winds, their direction and velocities.
4. Lightning (an important and the only weather agency causative of fires), its geographical distribution and frequency, with attention also to attendant precipitation.

These four are the really important elements. Temperatures are important mainly as affecting the percentage of relative humidity. High temperatures may be attended by high relative humidity, normal or subnormal temperatures are not infrequent with abnormally low percentages of relative humidity and an acute fire hazard. Absolute humidities are normally much higher in summer, the normal fire season, than in winter. For example, at Seattle the mean vapor pressure for January (at 5 p. m., local standard time) is 0. 219 inch, in August it is 0. 399 inch. The average temperature of the dew point at the same hour, varies from 36.2° in January to 52.6° in August. It is true that absolute humidity and temperature, considered in their relation to each other, do indicate the degree of the fire hazard, but this relationship resolves itself into the relative humidity, the direct index of the desiccating effects, or otherwise, of the atmosphere.

In certain districts investigators have stressed the importance of "duff humidity" as an index of the fire hazard, or rather as an index of the inflammability of the fire material. This is ascertained by periodic weighing of a fixed sample of the duff in situ, by measurements of the varying electrical resistance in certain plots, or by means of the "duff hygrometer," which latter shows, in effect, the relative humidity of the air in immediate contact with the duff particles. Without minimizing the importance of this method of measurement of the hazard it must be said that the condition of the duff is the resultant of antecedent and current weather conditions, particularly of precipitation and relative humidity, but itself is not a weather element. Accurate results from either of the three methods seem to require considerable preparation of sites and of frequent calibration of instruments. Hence, while of some importance as affording a "check" on the existing fire hazard it does not seem that such data need be included in any consideration of fire weather or fire climate except as supplemental material.

The four weather elements noted above being accepted as those directly affecting the fire hazard it is readily seen that the fire climatology of any region must be a summation of all manner of data concerning them.

It must also be premised that the general climatic characteristics of a region determine the nature of the forests and ground cover; that fire weather is an abnormal condition causing a fire hazard in excess of that normal for the season and region, so that the indices of increased hazard should be based on the departures of the several elements from their norms for each season and for the region considered. This being the case the fire climate will be determined by a record of the frequency and the degree of the abnormalities of the several elements, as well as by a record of their norms or means. And this will require a more extensive and intensive study than would be required to determine the general climate of a region.

Precipitation.—A complete record of the precipitation is essential. Normals should be established. The number of reporting stations will be determined by the general topographic and climatic characteristics of the region. For example, the States along the Pacific coast each have a zone of maritime and one of continental climate. Within each zone the local controls of precipitation are largely orographic. Annual totals vary from the order of 130 inches or more to that of 5 inches or less. There are important differences to windward and leeward of mountain ranges. Valleys of different axes have varying totals, within short distances. For such regions, that there may be an adequate survey, a seemingly excessive number of stations may be needed. For other regions, of more homogeneous terrain, only a fraction of the number may be ample.

Having adequate reports, what data shall be compiled? First, naturally, the normals. Monthly means are of value, but those for a shorter period will be of far greater utility. The decade, or rather the periods ending on the 10th, 20th, and last days of the month seem to be the most practicable subdivision, at least until such time as the uniform 4-week month shall have been adopted. This applies as well to computations of averages or means for all the other fire weather elements.

The character of the precipitation during the seasons is important. Does it occur in occasional heavy showers, with long dry intervals, or in more frequent light rains? How frequently can rains sufficient to moisten the forest floor and make for a period of safety be expected? To know this we should record the number of days with occurrences of each class of precipitation, from the least measurable through certain graduations up to 1 inch or more. The actual amounts may be made a matter of agreement, to the writer it would seem that records of the frequency of 0.01, 0.04, 0.10, 0.25, and 0.50 inch should be ample, or possibly more than ample, considering the clerical work required for the compilations.

Rainless periods, their duration and frequency, are of the utmost importance. It may be stated that prolonged rainless periods over sections which normally enjoy copious rains upset the normal equilibrium to a greater extent and cause a more acute fire hazard (given critical humidities) than do such periods of similar length over regions of scanty rainfall. The occurrence of dry periods of 4, 6, 8, 10, 15, 20, 30, and 40 days, with extremes, should be recorded, by the number of such periods beginning in each decade, or, possibly, for convenience, in each month. For an evaluation of the possible fire hazard over any area such data are of the greatest importance, but they can not be obtained from a scanning of decade or monthly averages of precipitation, in which the occurrence of the occasional drought is well hidden. Long dry periods have been found to be not infrequent even in the portion of western Washington which has local annual precipiation ranging from 80 to 140 inches.

It has been, by some, customary to object to the use of the hygrograph, on the ground that it is not an instrument of precision. Granted that there may be a slight inaccuracy, observation and study of the records for such instruments, frequent checks of many instruments, and a comparison with records from psychrometer obser-

vations, has convinced the writer that the probable error in the record from a well-calibrated instrument of the later models, as in the hygrothermograph of 1927, is no greater, if as great, as the probable error of a psychrometer observation, even made by a normally competent observer, especially where dry and wet bulb temperatures are reported to whole degrees. The sources of probable and possible errors in psychrometer readings are many and various, and are mostly due to the proneness of human kind to become a bit careless, besides, there is a frequent lack of continuity. On the other hand, the automatic instrument, once properly calibrated, and especially under normal woods exposure, will continue to make a good record indefinitely, with attention only once a week. Should a mechanical defect develop the fact is readily apparent, and corrections are usually simple. The continuity of the record is its great asset.

As competent observers can, and do, make acceptable records using the psychrometer, and as their cost is so much less than that of the hygrographs, they should be used at stations where but short-term records can be expected, furnishing valuable supplementary material by which the humidity survey may be considerably enlarged.

From the automatic records the following data can be segregated and compiled: The daily minima, with decade means; the number of hours of duration of the various critical percentages, with decade totals; the time of beginning of such critical periods, which can be averaged for the different parts of the season for the guidance of operators; the number of occurrences of critical periods, with decade averages; and the tendency toward persistence of such conditions for groups of two or more days; and a record of the frequency of nocturnal abnormalities (that is, critical conditions during the hours of normally high humidity). Some of these data may be extracted from the psychrometer records, but the actual minima, the duration, the hours of beginning, and the nocturnal abnormalities will not appear therein. From such records the decade averages for each of the three observations should be set down, in place of the average minima, that is, if the reports are of such continuity as to allow of valid averages.

Such a statistical analysis of the humidity element would afford just about all the information needed concerning this phase of the fire climate, but, for a large district having many stations, will require a great deal more clerical assistance than is now available. As to the "critical periods" to be recorded, the percentages of relative humidity, 40, 35, 30, 20, or any other, that are to be taken as indices of increased hazard, will depend altogether on local conditions and will require local determination based on a study of local problems. This determination should be a function of the forest protective agencies, or at least based on fire and weather history of the region and its subdivisions.

Winds.—Satisfactory records of wind directions and velocities are probably the most difficult of all to obtain, this despite the fact that accurate anemometers and elaborate recording instruments are available. The causes are two, lack of representative sites for exposure and the excessive cost of a complete instrumental installation. In a mountainous section it is difficult to find a site where recorded directions or velocities would be representative of any large area, or, given a fair site, to find an observer at that point. The effect of hills, mountains, and valleys on the local direction, and the local acceleration of wind movement due to the funnel effect of certain valleys, or to the convergence of two or more valleys, the local whirls, and other peculiarities, are too well known to be minutely described here. Lookout stations may give gradient directions, but the velocities are usually higher than over the wooded areas. And where funds are limited it is difficult to spare the large amount required for a complete installation of anemometer, supports, vane, and recording instruments. There should be, however, anemometers at least in representative geographical distribution, and as many other accessories as funds will allow. For record purposes the daily maxima, with duration, the prevailing directions, and the 4-hour average movement, with means, are probably the most important. Parenthetically, the hygrograph is a good auxiliary for determining basic wind direction; from its trace one can determine whether the local currents, from whatever direction reported, have their origin from the moist, or coastal direction, or from the dry interior.

Lightning.—For lightning reports we must depend altogether, as yet, on observations by eye and ear. Completeness of record is dependent on an adequate distribution of reporters and on their diligence in noting each manifestation within their districts. Storms may be classified as severe, moderate, or light, dependent on the number of flashes or peals observed or heard, with accompanying notes as to the amount of the accompanying precipitation. For record purposes a number of representative stations should be selected, the number again varying with the nature of the territory, and for each, the number of storms, in the several classifications, set down, by totals for each decade. Supplemental data, from protective organizations, as to the number and location of lightning fires, will form a most valuable adjunct to this record, in fact, will be indispensable if a correct estimate of the importance of lightning as a causative agent is to be formed.

For record of the geographical distribution and rate of progress of each storm base maps of the area, on which the location and hour of each report may be plotted, one for each date with storms, should be used. These give a graphic record of results which may be readily compared with the graphic presentation of the causative pressure and temperature distribution shown on the preceding and current synoptic charts, besides affording a permanent record.

It is realized that to set down so much of detail regarding each of many stations will require much time and labor and will result in a large volume of data. But no accurate determination of the fire climatology of a region can be made without a full knowledge of just such details. Having all this information and by giving a numerical value to the salient phases of each element, increasing as the fire hazard would be increased, by taking the sums or average for all elements a rating number might be assigned each section or subsection, as a coefficient of the fire hazard for that section which would allow of a quick comparison. The details of such a rating will afford interesting material for future conferences between the several fire-weather specialists and the protective agencies.

In the ultimate rating of the fire hazard, however, the human element can not be ignored. Lightning is the major cause of fires only in certain mountain sections. The activities, present or those probable in the future, of the logger, the land clearer, the hunter, fisher, and other vacationists must be considered.

RELATIVE HUMIDITY AND SHORT-PERIOD FLUCTUATIONS IN THE MOISTURE CONTENT OF CERTAIN FOREST FUELS

By A. GAEL SIMPSON

Forest protectionists in the Douglas fir region of the Pacific Northwest are probably more interested in relative humidity than in any other one weather element, both because of its effect on fire and on forest fire fuels. Unquestionably it is a powerful factor in fire behavior.

One important function of humidity is to cause changes in the moisture content of the forest fuels. In general, low relative humidity tends to rob the fuels of moisture, while high humidity contributes moisture to them.

The most rapid moisture changes may be expected to occur in light, porous materials having a high ratio of surface-to-volume such as weeds, mosses, leaves, twigs, and a very thin layer on the outside of the larger materials such as branches and logs. Though the light débris usually represents but a small portion of the total volume of fuel on forested or cut-over areas, it is the kindling and fire carrier to the heavier stuff. Flash materials occupy a place of about the same importance in forest fires as does paper and kindling in building a fire in your cook stove or furnace. The dryness of the kindling, whether it be in the forest or in the kitchen range, has much to do with whether or not the fire will start.

The moisture condition of the forest kindlings can, and often does, change astonishingly in a very short space of time. They may be saturated and literally dripping with dew in the morning, yet dry out to a highly inflammable condition before the day is over. Hence, the fire fighter watches the humidity with anxious eye and notes its effect on the flash fuels, for when they have dried to inflammability danger is at hand. Conversely, after they have absorbed moisture in excess of the critical value, the chances of fires starting or spreading are enormously reduced.

It has been said that "some materials burn; others are burned." The thought might be revised to read thus: "Sometimes a material burns; at other times it is burned."

On a going fire, the beginning of the fire day or fire period dates from the time such light materials as fern and outside of snags begin to burn and carry fire. Enough heat may be generated to consume some of the more sluggish fuels that are still too damp to ignite without this additional drying. The one burns, the other is burned. As the day advances, the humidity falls and the fuels continue to give off moisture to the atmosphere so that additional materials are shifted from the "are burned" to the "burn" class until a roaring climax is reached when all of the fuels are at the peak of the "burn" condition. Then, when the humidity rises, the more moisture sensitive fuels are first to absorb water vapor and enter the "are burned" class and are followed in order by the denser fuels.

Experience points to a close affiliation between fuel moisture and atmospheric humidity and laboratory experiments bear this out. As a basis for a study of this apparent relationship, hourly measurements were made of the moisture content of 21 forest fuels, together with concurrent hydrometric data at the Wind River laboratory of the Pacific Northwest Forest Experiment Station. Samples of the following materials were used: Braken fern, fireweed, hawkweed, pearly everlasting, creeping blackberry, Oregon grape, salal leaves and twigs, fire-killed vine, maple leaves, gray moss from Douglas fir trees, Douglas fir, western hemlock, western white pine, lowland white fir duffs, decayed Douglas fir wood and decayed hemlock wood, decayed sap of Douglas fir snags, outside one-eighth inch of Douglas fir snags, Douglas fir needles and twigs from slash, Douglas fir twigs, bark from Douglas fir snags, and bark from hemlock snags.

During the period covered by the measurements, the fuel samples were suspended 4½ feet above the ground level in wire-screen baskets of 1 cubic foot capacity. In all something over 2,000 measurements were made. Graphing 72 consecutive hours of these data showed that the daily fuel moisture curves had a form similar to the daily relative humidity curve. However, the peaks and valleys in the fuel moisture curves did not exactly coincide with those in the humidity trace. Instead, the fuel moisture lagged appreciably behind the relative humidity. The amount of this lag, or inertia, seemed to vary with the kind and condition of the fuel.

Both the humidity and moisture-content curves normally show a daily periodicity in that there is a daily rise and fall in atmospheric and fuel moisture. Usually they attain maximum values during the night and fall to a minimum during the day.

The periodic nature of the data suggested one of the two methods of analysis used—a very convenient method but one which, so far as I know, has not heretofore been applied to studies of this sort, though frequently applied to other types of data.

To illustrate the method, I have used moisture-content measurements of Douglas fir duff together with appropriate humidity data. The solid line curves show averaged values for each hour of the 24, based on 72 consecutive hourly measurements.

* * * * *

That may seem like a short time, but remember we are making comparisons of simultaneous observations rather than seeking normals. Measures of the sufficiency of the data will be discussed later. Appropriate sine curves have been passed through the data as shown by the broken lines and their respective phase angles. computed. The difference in phase between the two curves represents the best value for the lag of the duff moisture curve behind the relative humidity curve. In this case an hour and a half.

Similarly the lags of a number of other fuels were computed. However, I will give only a few representative ones.

It was found that fern, representing the weed group, lags one hour; the outside one-eighth inch of Douglas fir snags, representing that part of the snag first likely to ignite, lags about an hour and a quarter; Douglas fir duff, representing the duff fuels, lags an hour and a half; and wood, decayed to the disintegrating stage, lags a little more than two and one-quarter hours.

A good relationship between relative humidity and duff moisture has been indicated, and by inference, a relationship may be expected to exist between humidity and other fuels more or less similar in character. Two questions present themselves, namely, how good is this apparent relationship, and, can fuel moisture be estimated from appropriate humidity data.

The relationship appears to be reasonably close. For instance, a correlation of the average relative humidity during the 60-minute period immediately preceding each measurement of the moisture content of braken fern gave a positive correlation coefficient of 0.97, which is not too far removed from 1, or perfect correlation.

Douglas fir duff moisture when correlated with the average relative humidity for 60-minute periods ending one hour before the moisture measurements also gave a positive correlation of 0.97. (The sine curve analysis showed duff to have a lag of about one and one-half hours.) Correlation of the moisture in decayed wood with humidity data likewise yielded a positive correlation of 0.97. Of the 21 fuels studied, western white pine duff gave the best correlation, 0.98, and lowland white fir duff gave the poorest, 0.89.

As indicative of the sufficiency of the data for correlation purposes, the standard deviations of the correlation coefficients were found to be of the order of ±0.01.

Estimates of current fuel moisture conditions based on atmospheric relative humidity show standard errors of estimate ranging from ±2.3 per cent moisture for pearly everlasting down to but ±0.3 per cent moisture for Douglas fir twigs. For example the standard error of the estimates of braken fern moisture was calculated to be ±1.6 per cent moisture. Attaching the usual significance to the standard error of estimate it is assumed that, with a normal distribution, about two-thirds of the errors resulting from the use of the estimating equation will not exceed ±1.6 per cent. The greatest errors were found to occur when the estimates were based on high humidity values such as often occur at night.

No attempt has been made here to evaluate the seasonal trend of fuel moisture nor the eccentric fluctuations due to precipitation, for that requires a somewhat different treatment. Nevertheless, the study does furnish a method of approximating fuel moisture during the mid-season dry weather.

It is hoped that the results of the study may be of assistance to the fire fighter in estimating the length of the fire day, its severity, and the hours of fire danger on areas where the types of fuel are known.

On going fires it should aid in anticipating the degree of inflammability of the various fuels and also aid in the proper disposition of the fire suppression forces.

Also a knowledge of the degree and rapidity with which the various kinds of forest fuels respond to relative humidity is essential to good slash burning technique. Estimates of fuel moisture should help the slash burner to calculate the proper time at which to fire his slash in order to get the best burn with a minimum danger of the fire spreading beyond the slash area.

NOTES, ABSTRACTS, AND REVIEWS

The Quarterly Journal of the Royal Meteorological Society.—Though a good many copies of the excellent Quarterly Journal of the Royal Meteorological Society are received by meteorologists in the United States, there are interested readers who may not have seen this Journal recently. A brief review of the contributions in the January, 1930, issue shows the importance of this outstanding meteorological quarterly.

M. G. Bennett discusses "The physical conditions controlling visibility through the atmosphere." First, he worked up the theory with the aid of laboratory experiments, and then tested his conclusions in the field. The relative effects of screening, diffusion, and glare upon visibility are expressed in an empirical formula. Mr. Bennett notes the difference between even change in visibility when the effect is simply one of glare, as in the case of smoke, and the sudden change from moderate visibility to no visibility in case of fog, which diffuses light.

Dr. Lewis F. Richardson presented results on "The Reflectivity of woodland, fields and suburbs, between London and St. Albans," obtained from airplanes. The reflectivity for red light ranged from slightly under 4 per cent for woodland and the reservoir to 6 per cent for brown standing wheat. For green light, the reflectivity ranged from 3½ per cent for tall woodland to 8½ per cent for bare land. The reflectivity of blue light was still less, ranging from about 2 per cent for wood land and green fields to 4 per cent in villas and gardens. The reflectivity of sand, cement slabs, or earth when dry is roughly double what it is when they are wet. The reflectivity of water, so conspicuous at nearly grazing incidence, falls off to nearly 2 per cent incidence according to Fresnel's formulæ; so that of the light reflected from the reservoir about one-half comes from below the air-water interface.

Thora C. Marwick presented observations on "The electric charge on rain," made in New Zealand. Of all the rain measured, 76.5 per cent was positively charged; of thunderstorm rain 94.6 per cent was positively charged; of ordinary rain 79.5 per cent; and of a little drizzling rain, 100 per cent. Sleety rain accompanied by hail had a considerable negative charge.

J. E. Clark, and I. D. Margary presented a general article on Floral isophenes and isakairs, for England. Phenological dates for flowering plants in England when averaged over a 35-year period are practically the same as for a 30-year period. The 35-year normals have been used as a basis for determining departures in individual years. Departures were read by comparisons between the average map and the maps for each year for each intersection of half degrees of longitude and latitude. The earliness and lateness of the season is not always related in an obvious manner to the temperature or sunshine of the preceding few months. Conditions in the previous fall may have something to do with the dates.

E. W. Bliss in "A study of rainfall in the West Indies," showed that the March to May pressures in central Siberia and Charleston, S. C., and temperatures for St. Vincent indicate the West Indies rainfall for June to December following, with the correlation coefficient of 0.69. High rainfall follows a weak Azores high. The delay is thought to depend upon the westward movement of ocean waters in the north Atlantic.

Sir Gilbert T. Walker in a note "On the mechanism of tornadoes" suggested that tornadoes are whirls essentially on a horizontal axis the equatorward end of which dips to the earth. This idea was not generally acceptable to those who discussed the paper.

Among the notes, is a discussion of "Winter thunderstorms in the British Isles," in the period from October to March, inclusive. During the past three winters the number of days on which thunderstorms occurred anywhere in the British Isles are 96, 92, 69. The stormiest regions are the west and north of Ireland, the northwest of Scotland and the English lake district.

Reviews of the book by August Schmauss, and Albert Wigand, "Die Atmosphäre als Kolloid," and of W. P. von Poletika's "Klima and Landwirtschaft Russlands," are included in this issue.—*C. F. B.*

Climatology of the Virginias[1] (*by E. Ray Casto, Emory and Henry College*) [*author's abstract*].—The Virginias lie in one of the favored climatic regions of the world. Each of the climatic factors is markedly influenced by the widely diversified topography of the region. And the divergent winds tend to equalize other climatic elements and to give less variable climate.

[1] Submitted as a thesis as part requirements of the degree of Ph. D. at Clark University Worcester, Mass., in 1926.

The average sunshine for the Virginias as a whole is above 52 per cent of the possible amount—for Virginia 56 per cent and for West Virginia 46 per cent. There is a decrease in sunshine with increase in latitude or proximity to the principal storm tracks farther north. Sunshine and cloudiness are nearly complementary. Cloudiness increases and sunshine decreases here with altitude, latitude, exposure, and relative humidity. Elkins on the windward side of the mountains has the greatest number of cloudy days, 156, and Lynchburg on the leeward side of the mountains has the least, or 93 cloudy days.

The effect of latitude on temperature is best seen in the Coastal Plain. The dominance of latitude is shown in the east-west trend of the isotherms, the temperature gradient being about 2.5° F. per latitude degree for the year and even greater in winter. Along the western border of West Virginia the gradient is 1.7° per degree of latitude and at the eastern border of the Allegheny Plateau 2.0°.

Altitude exerts its influence on temperature over the Appalachian Highlands. It even becomes the dominant control. The vertical temperature gradient between Parkersburg and Bayard is 1.1° per 330 feet. It is greatest in summer.

There is a more uniform distribution of temperature in summer than in winter but the isotherms are more crowded over the Appalachian Highlands in summer. The general plan of the isotherms is much the same throughout the months, conforming largely to topographic conditions at all times. The isotherms reach their most southern limit in January but the northward advance is scarcely noticeable in February. In fall and early winter the ocean gives a northward bend and in summer a southward trend of the coastal portions of isotherms. Mean annual ranges of temperature are 34°–39° in the south and 40°–45° in the north. The regions of high altitude have a lesser range, while the modifying effect of the Atlantic shows in the slight range along the coast. The mean maximum and mean minimum isotherms have a tendency to parallel the coast, the ocean waters generally preventing great extremes of temperature. The absolute maxima temperatures range from 94° F. at Terra Alta and at Wytheville to 110° F. at Wheeling. The absolute lowest temperatures show great local diversities, the lowest being in the valleys. Lewisburg has reported −37° F. Lost Creek has the greatest annual range of temperature, 137 degrees, while Cape Henry has the smallest, 98 degrees.

There is a close correlation between frost and temperature maps. Also stations having much fog have longer frost-free periods than near-by ones without. Along the coast the last killing frost occurs before April 1, while at Bayard the average date is May 25; the average date of the first killing frost at Bayard is September 19, while over a part of the Tidewater it is later than November 10, thus the number of frost-free days ranges from 240 along the coast to 115 at the headwaters of the north branch of the Potomac.

The effect of the increase in latitude on frost is greatest along the Ohio border of West Virginia, where in a difference of 2.5° of latitude there is a change of 45 days in the frostless period.

Rainfall is well distributed through the year. The heaviest precipitation in the Virginias, 50 to 65 inches, falls on the west slope of the Alleghenies, while the lightest, 30 to 35 inches, involves a considerable area within the valley, lying in the lee of the higher lands.

Pickens, 2,697 feet, receives 65.08 inches of precipitation, while Charleston, 597 feet, in direct line up the prevailing winds from Pickens receives 46.02 inches, a difference of 9.1 inches per 1,000 feet of elevation.

The Appalachians cast their strongest rain shadow in winter and early spring, when the cloud base is lowest—the decrease from highland stations to lowland stations being 5 inches in January and 4 inches in each of the months December, February, and March, and only 2 inches in summer and fall. The influence of the Atlantic on precipitation appears to extend little, if any, beyond the Allegheny front.

For the most part summer is the season of heaviest precipitation, due to the persistence of the prevailing winds from the Gulf of Mexico and from the Atlantic. The large amount of moisture available at this season, therefore, yields abundant rainfall by local convectional activity, intensified now and then by summer cyclones.

Winter has abundant precipitation attending the almost constant procession of cyclonic storms.

Spring has the advantage of winter's accumulated precipitation and of marked changeableness of temperature, therefore precipitation is frequent but not so abundant as in winter or in summer.

Fall precipitation in the Virginias is low. Convectional activity has decreased and cyclonic influence has not yet become very marked.

The lowest average annual snowfall is 6.9 inches at Cape Henry and the greatest is 112.5 inches at Pickens. Snowfall increases with increase in latitude, altitude, and in general, decreases with proximity to the ocean. The Appalachians cast marked snow shadows over the valleys to leeward. Pickens, at 2,697 feet, with 112.5 inches and Woodstock at 927 feet, with 26 inches, show this shadow effect. Snow falls in some part of the Virginias 10 months of the year. In October snow has occurred everywhere in the Virginias except in a narrow belt along the Atlantic coast.

Thunderstorms occur in any month, but more than half of them in summer, the season of greatest convectional overturning. Elkins averages 28 during the summer and less than two during winter. This ratio holds, in general, for the other stations.

Hail is most frequent in spring and early summer, being more common in higher altitudes and more northerly latitudes.

The monthly course of absolute humidity runs parallel to the monthly course of temperature. Relative humidity increases with increase in latitude and altitude. April (except March, at Mount Weather) is the month of lowest relative humidity and September is the month of maximum.

Early fall is the period of maximum fogginess, except for stations of the coastal plain. At Cape Henry and Norfolk winter is the foggy season.

In the highland sections topography influences the wind direction, while on the coastal plain regularity in topography allows for a more even distribution of the winds. The strong northwest winds of winter change during the spring by way of west to a southwesterly or southerly direction in the summer months. Fall brings the northeast wind, which is most marked at stations on the coastal plain as there is less local topographic deflection here.

Wind velocities increase with altitude. An exception to this is found in the case of Elkins, however, which is influenced by local topography. The winter months are those of highest wind velocities and the maximum number of gales, but, except for Mount Weather and Cape Henry, there are few days with gales.

The Chicago snowstorm of March, 1930.—The discussion by Editor Alfred J. Henry of the storm of March 25, 1930, at Chicago, appearing in the MONTHLY WEATHER REVIEW of April, 1930, has been read with much interest, largely because a brief study has been made of the storm by us. Some general notions concerning the storm were deduced from a study of the 3-hour maps for the period. The weather was more insistently noticeable in its disastrous exhibition of snowy violence at Chicago but the Chicago-New York airway was under the domination of the changeable actions of the storm for two days and both summarizing and flying were difficult on this line. It is perhaps of interest to state that the summaries issued every three hours at this station were distinctly pessimistic as to the conditions at the western end of the airway (Chicago) until 5 p. m. March 26, 1930, when there appears this favorable sentence: "There will be an improvement in ceilings and lessening of snowfall in central Pennsylvania and ceilings will also rise somewhat at Chicago." The end of the snow was in sight at that time.

One of the similarities which is outstanding in comparing the 1888 blizzard with that of the present paper is that both storms had great depth as Professor Henry has stated, but also that they had two or three centers of depression. The 3-hour maps show these in distinct form by the wind motion and in the variations of pressure.

This study was instituted as a result of the phenomena observed here at Cleveland. About noon of March 25 conditions as observed indicated the passage of the center of the low, but again on March 26 about 7 a. m. another center passed. This dual action is traced across western and central Pennsylvania on the marginal charts of the same large sheet (not reproduced). The general conclusion is that a warm front dominated the conditions until the passage of the first depression; then there followed a period of cold with light winds but with little pressure recovery. Behind this came the pressure rise and a second temperature fall this time attended by westerly winds of definite drift.

Three stations on mountain tops, Greenwood, 175 miles east of Cleveland, elevation 2,300 feet; Winkelblech Mountain, 245 miles east of Cleveland, elevation 2,100 feet; and Park Place, 300 miles east of Cleveland, elevation 1,940 feet; were selected between here and New York for investigation as to the changes during the period of the passage of the depressions. These results are shown on the marginal spaces (not reproduced). The temperature drop at Greenwood occurred at 4 p. m. of the 25th, three hours later than at Cleveland, and shows different characteristics. At Winkelblech Mountain it occurred about three hours later than at Greenwood and at Park Place about three hours further. The warm front appears at each of the mountain stations but is brief and small at Cleveland. At Greenwood there was no fog in the warm front but a thunderstorm occurred when the front passed and a fog sets in when the cold front fully arrived, in this case fog being low clouds which covered the station. At Winkelblech there was fog in both fronts, a good example of a change of almost 20° in the dew point in six hours. At Park Place the fog occurred in both fronts, a drop of over 20° being shown in the dew point in 8 hours. Squalls first of rain and later of snow marked the weather at all three hill stations. The barometer readings shown were taken from corrected aneroids and are reliable.

On a set of four other "green" base charts we have drawn the squall line positions for the eight observations per day on the four days March 23 to 26, inclusive (not reproduced). In general these lines show a normal direction of movement and twist but an abnormally slow motion.

Two other charts show that the identification of one of the three subcenters from hour to hour is fairly plain although the small changes in the central pressure and circulation are not even fully discounted by stations as closely adjoining as those of the airway service. These maps have not been inclosed. Another feature of unusual interest is the fact that pressure in the area east of the ninety-second meridian failed to show any considerable rise for a period of three days. Increases of 0.06 inch or more per three hours were only seven in number for the entire period from 5 p. m. March 23 to 8 a. m. March 26. The falls were numerous, showing plainly the increasing intensity of the storm and its spreading power. As is frequently true of lows in this area it is generally true that it is unsafe to predict betterment of conditions whatever the wind and temperature may show if the pressure fails to recover in their rear, or if it settles somewhat.

One feature of the pressure distribution which called our attention toward the chance for a developing storm was the pressure trough on the central Gulf coast. Our conclusion that the storm was retarded by this low is about as strong as our conclusion that the northeastern "high" blocked its progress, and we believe that the masses of warm air associated with this small Gulf disturbance had to find an outlet to the north with the natural result that they tended to reduce pressures there.

Reference was made in the REVIEW to upper air motions. Few balloon runs were obtained here but the upper clouds when observed were from compass points having considerable south component. No data available appear to have given us any reasonable basis for expecting the great development which did occur.

Strangely enough, it was one storm in which the lonely observer with one aneroid barometer was more likely to have made a successful set of predictions than were some of the more completely informed forecasters with a wide field of pressure readings. The explanation for this is reasonable when we take one isobar such as the 29.7 and draw its position for each three hours, thus depicting its steady and wide expansion and at times its actual movement toward the west on the western sides of its curve.

C. G. ANDRUS, *Meteorologist.*

Weather conditions during the summer of 1930.—The drought in the United States during the months of July and August, 1930, was paralleled in Europe by a period of rain and cold not equaled since 1864, it is stated. Although the first week of July was dry and warm, the average daytime temperature for the entire month was 0.7° C. below normal; the average maximum temperature was 0.8° below normal, but the average minimum was 0.1° above normal owing to the warm weather during the first week. During the first 20 days of August the average morning, maximum, and minimum temperatures were respectively 1.0°, 1.5° and 0.5° below normal.

The precipitation of moisture during the month of July averaged 142 millimeters (5.59 inches), the normal being 71 millimeters or 2.79 inches, this having been the wettest month since 1855, according to the records of the weather service. The rainfall during the first 20 days of August was almost 100 per cent above normal, and furthermore there were heavy winds on several occasions which did much damage to the growing crops.

The number of hours of sunshine during July was 180, of which 70 hours were credited to the first seven days, the total thus having been 86 hours below the normal of 196 hours. During the first 20 days of August the number of hours of sunshine was 101 while the normal number is 116. A total of 42 hours of the entire number of hours of sunshine up to the 20th of the month occurred during the last four days of the period. *U. S. Consular Report.*

Ergebnisse der Registrierballonfahrten ausgeführt vom Geophysikalischen Institut der Universität Leipzig und der Sächs. Landeswetterwarte in den Jahren 1926 u. 1927.—The results of the sounding-balloon ascents at Leipzig in 1926 and 1927 have been published in mimeographed form, including brief discussion and both tables and graphs for each ascent. The frequent occurrence of minor temperature inversions in the free air is striking, as is also the usual coincidence of the maximum of relative humidity with the beginning of a temperature inversion. Temperature-isopleth diagrams for certain series of days show in one instance a sharp oscillation in the course of a single day, and extending to a height of 10 or more kilometers, with approximately the same amplitude, of 5° C. at all heights. A minor low was passing.—*C. F. B.*

P. R. Krishna Rao on the distribution of temperature in the lower stratosphere.[1]—The author has shown by means of graphs and tables some striking relationships between the inversion in the lower part of the stratosphere and the temperature at the tropopause (Tc). It is found that lower values of Tc are associated with thicker and stronger inversions in the lower layers of the stratosphere. It is also shown from the mean annual lapse rates that the stratospheric inversion is only about 3 to 4 km. thick in the temperate regions but much thicker in the tropical and subtropical regions. The upper limit of this inversion in the latter regions is above the highest altitudes reached by observations thus far.

The fact is pointed out that the stratosphere is not an isothermal region as it is sometimes believed to be but a region that definitely begins with an inversion of temperature. The following qualitative explanation is given for the existence of this inversion and its latitudinal variation and for the relationship between Tc and the strength and thickness of the inversion on the basis of convection in the troposphere:

It is well known that the actual temperature distribution in the atmosphere is not determined by radiation alone but is fundamentally influenced by turbulence and convection in the region of the lower atmosphere in which the water vapor content is appreciable. The effect of superposing convection on radiation equilibrium condition is to increase the temperature in the lower layers mainly by the latent heat liberated from the condensation of water vapor. Active convection may be expected to continue up to the height at which the equivalent potential temperature [2] is the same as the equivalent potential temperature at the starting point (ground). Above this limit, there will be a certain amount of "forced mixing" due to the disturbance caused by the convection below. This mixing will cool the upper layers because the lower layers are potentially colder than the upper. The tropopause can make its appearance only above this region of forced mixing. If the convection below is sufficiently active this mixing will raise the tropopause and lower the temperature there below the radiation equilibrium temperature of the stratosphere.[3] As there can be no convection above the tropopause there will be a tendency to go back to the radiation equilibrium temperature. This approach from a lower to a higher temperature results in an inversion.

The stronger the convection the greater is the cooling in the uppermost regions of the troposphere which produces lower values of Tc and hence stronger inversions above. Since on the average there is more convection in the tropics than in the temperate regions and more in summer than in winter, it follows that the stratospheric inversion should be stronger in the tropical than in the temperate region and stronger in summer than in winter. The height range through which the approach from Tc to the radiation equilibrium temperature of the stratosphere occurs determines the thickness of the inversion above the tropopause; this is larger, the larger the deviation of Tc from the radiation equilibrium temperature of the stratosphere.

If the stratospheric inversion owes its origin to convection in the troposphere, we should expect some significant relationships of temperatures and lapse-rates in the troposphere with Tc and the stratospheric inversion. Some preliminary calculations have shown that there is a strong negative correlation between the temperature at 10 gkm. and the fall of temperature between 10 and 16 gkm. over Agra. (16 gkm. is about the mean height of the tropopause over Agra). Blair [4] has shown from American observations that the seasonal variation in the height of the region of largest lapse-rates in the troposphere is similar to the variations of the height of the minimum temperature in the free atmosphere. This seems to hold for other places also.

The author states that:

for various reasons, viz, the existence of maximum concentration of ozone in the atmosphere at a height of 30–50 km., the reflection of sound waves from the upper atmosphere and Lindemann and Dobson's theory of meteors, it is, however, fairly certain that above 40 km. there is a rapid increase of temperature with height.

This opinion is not yet held by many meteorologists since all of the phenomena mentioned can be satisfactorily accounted for in other ways.—*L. T. Samuels.*

[1] India Meteorological Department. Scientific Notes, Vol. I, No. 10.

[2] Equivalent potential temperature θ is the temperature which would be taken up by a mass of air at "equivalent temperature" θ when brought adiabatically from its pressure to a pressure of 1,000 mb. $\theta = T \times \frac{Lx}{c}$ where T is the dry bulb temperature, x the humidity-mixing ratio corresponding to the existing vapor pressure at T, c the specific heat of air at constant pressure and L the latent heat of condensation. For greater details refer to Ind. Met. Memoirs, Vol. XXIII, Part I.

[3] According to the "classical" radiation equilibrium theory the temperature distribution with height is practically isothermal at 220° A. See Die Arbeiten des Preuss: Aeronautischen observatorium bei Lindenberg Band XIII, p. 6.

[4] Bull. of Mt. Weather Obs'y, Vol. IV, p. 6.

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING SEPTEMBER, 1930

By HERBERT H. KIMBALL

For reference to descriptions of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this volume of the REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged close to the normal intensity for September at Madison, Wis., and Lincoln, Nebr., and slightly below normal at Washington, D. C.

Table 2 shows an excess in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at all stations except Fresno for which normals have been computed. The excess was marked at Washington, Madison, New York, and La Jolla.

Skylight polarization measurements obtained at Washington on 4 days during the month give a mean of 47 per cent and a maximum of 50 per cent on the 23d. At Madison measurements obtained on 15 days give a mean of 60 per cent and a maximum of 70 per cent on the 17th. The values for Washington are decidedly below, and those for Madison only slightly below, the corresponding September averages for the respective stations.

TABLE 1.—*Solar radiation intensities during September, 1930*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	87.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 4	9.47	0.67	0.80	0.94							7.29
Sept. 6	16.79					1.16					10.21
Sept. 9	11.81	0.46	0.53	0.56							9.47
Sept. 11	11.81	0.56	0.66	0.82	1.02						10.59
Sept. 22	13.13				0.86						12.68
Sept. 23	14.10		0.42	0.62	0.75	0.97					11.81
Sept. 26	16.79	0.73	0.86	0.98	1.09						15.11
Sept. 29	5.36	0.81	0.92	1.02	1.24						4.75
Sept. 30	6.50				0.94	1.15	1.18	0.85	0.67	0.56	6.02
Means		0.65	0.70	0.82	0.98	1.09	(1.18)	(0.85)	(0.67)	(0.56)	
Departures		−0.04	−0.05	−0.05	−0.07	−0.23	+0.13	+0.00	−0.06	−0.10	

TABLE 1.—*Solar radiation intensities during September, 1930*—Con.

Madison, Wis.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	87.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 2	12.68					1.38	1.23				10.97
Sept. 3	7.87	0.80	0.92	1.06	1.24	1.39	1.18				6.76
Sept. 4	9.83				1.14						8.81
Sept. 8	9.14				0.99						7.29
Sept. 9	9.83				1.08	1.31					8.18
Sept. 10	10.59						0.91				7.87
Sept. 11	9.47				1.00		0.97				9.47
Sept. 12	11.38						0.73				15.11
Sept. 16	8.48		0.86	0.97	1.17		1.20				6.02
Sept. 17	6.02		0.98	1.10	1.28	1.48	1.26				6.76
Sept. 18	7.29			0.99	1.17	1.39	1.06				8.18
Sept. 19	11.38				0.97	1.32					13.13
Sept. 20	5.36				1.30	1.52					4.17
Sept. 22	7.87				1.16		1.11				7.87
Sept. 23	13.61				1.05						15.65
Sept. 27	4.57				1.28						4.75
Sept. 29	4.95						1.24				6.02
Sept. 30	5.16		1.06	1.17	1.32						4.57
Means		(0.80)	0.96	1.06	1.15	1.40	1.09				
Departures		−0.08	+0.05	+0.04	−0.01	+0.03	−0.06				

Lincoln, Nebr.

Sept. 2	8.48					1.38	1.16	0.97	0.81	0.70	7.87
Sept. 3	9.47		0.81	0.82	1.00						10.59
Sept. 5	11.81			0.74	0.98						14.60
Sept. 13	14.60		0.81	0.90	1.11	1.35					15.11
Sept. 15	8.81					1.41	1.21	0.99	0.90	0.74	7.29
Sept. 16	8.81		0.90	1.06							6.02
Sept. 17	7.04	0.84	0.94	1.06	1.21	1.46	1.16	0.97	0.79	0.69	7.04
Sept. 18	10.59		0.74	0.88	1.10	1.43					9.83
Sept. 19	9.47						1.02	0.89	0.72	0.63	9.14
Sept. 22	9.83			0.86	1.07						13.13
Sept. 27	7.04				1.23	1.44	1.25	1.05	0.88	0.76	4.37
Sept. 28	5.79						1.25	1.06	0.90	0.77	4.17
Sept. 29	6.27		0.85	0.95	1.13		1.09	0.91	0.76	0.65	8.81
Sept. 30	5.16		0.84	0.99	1.20	1.43					4.57
Means		(0.84)	0.84	0.92	1.11	1.41	1.16	0.98	0.82	0.71	
Departures		+0.08	−0.02	−0.08	−0.07	+0.01	+0.01	+0.01	−0.01	−0.02	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning	Average daily totals									
	Washington	Madison	Lincoln	Chicago	New York	Pittsburgh	Gainesville	Fresno	La Jolla	Miami
1930										
Sept. 3	404	396	307	302	352	366	----	546	455	428
Sept. 10	390	411	399	292	253	318	360	545	333	462
Sept. 17	404	430	456	320	377	355	427	457	327	517
Sept. 24	438	306	401	216	288	294	427	410	312	487
	Departures from weekly normals									
Sept. 3	+26	+28	−109	−8	+51	----	----	−19	+110	----
Sept. 10	+15	+66	−7	+5	−44	----	----	+13	+36	----
Sept. 17	+50	+86	+68	+50	+95	----	----	−35	+21	----
Sept. 24	+92	+15	+57	−19	+29	----	----	−44	−38	----
Accumulated departure on Sept. 30	+5,957	+1,708	−1,841	+861	+896	----	----	−2,304	−2,030	----

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1930	h m	°	°	°			
Sept. 1 (Naval Observatory)	11 59	−79.0	84.4	+5.0	----	68	----
		−15.5	147.9	+9.5	40	----	----
		−13.5	149.9	−13.5	6	----	----
		+25.0	188.4	+7.5	----	15	----
		+37.5	200.9	−10.0	----	28	157
Sept. 2 (Naval Observatory)	10 51	−74.5	76.3	−8.0	93	----	----
		−65.5	85.3	+5.0	----	62	----
		−2.0	148.8	+9.0	46	----	----
		−0.5	150.3	−13.0	6	----	----
		+51.5	202.3	−10.0	----	18	225
Sept. 3 (Naval Observatory)	10 11	−79.0	59.0	−16.5	28	----	----
		−61.5	76.5	−7.0	108	----	----
		−53.5	84.5	+5.0	31	----	----
		−9.5	128.5	+5.0	----	43	----
		+10.5	148.5	+9.0	40	----	----
		+12.5	150.5	−13.0	6	----	----
		+65.0	203.0	−10.0	----	15	271
Sept. 4 (Naval Observatory)	10 55	−84.0	35.4	+16.5	231	----	----
		−63.5	60.9	−17.0	----	62	----
		−48.0	76.4	−7.0	68	----	----
		−39.0	85.4	+5.0	6	----	----
		+6.0	130.4	+5.0	----	185	----
		+24.5	148.9	+9.5	37	----	----
		+24.5	148.9	−11.0	2	----	591
Sept. 5 (Naval Observatory)	12 50	−71.5	38.6	+16.0	278	----	----
		−51.0	59.1	−17.5	----	49	----
		−33.5	76.6	−7.5	65	----	----
		−29.5	80.6	+5.5	----	9	----
		+21.0	131.1	+5.0	----	201	----
		+38.5	148.6	+9.5	31	----	633
Sept. 6 (Naval Observatory)	10 40	−59.5	38.6	+16.0	262	----	----
		−38.5	59.6	−17.5	----	15	----
		−21.0	77.1	−7.5	65	----	----
		−17.5	80.6	+6.0	----	6	----
		+8.5	106.6	−3.5	----	9	----
		+33.0	131.1	+5.0	----	247	----
		+45.0	143.1	−13.0	15	----	----
		+51.0	149.1	+9.5	31	----	650
Sept. 7 (Naval Observatory)	11 9	−46.5	38.1	+16.0	170	----	----
		−24.0	60.6	−17.0	----	3	----
		−8.0	76.6	−7.5	62	----	----
		−0.5	84.1	+6.0	----	15	----
		+22.5	107.1	−4.5	3	----	----
		+36.5	121.1	−11.5	3	----	----
		+49.0	133.6	+4.5	----	231	----
		+64.5	149.1	+9.5	9	----	496
Sept. 8 (Naval Observatory)	12 36	−33.0	37.6	+16.5	185	----	----
		+6.0	76.6	−7.5	56	----	----
		+15.0	85.6	+5.5	----	15	----
		+50.5	121.1	−11.5	9	----	----
		+63.5	134.1	+5.0	----	170	435

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1930	h m	°	°	°			
Sept. 9 (Naval Observatory)	10 44	−21.0	37.5	+16.0	247	----	----
		+18.5	77.0	−8.0	46	----	----
		+28.5	87.0	+5.5	6	----	----
		+78.0	136.5	+4.5	185	----	484
Sept 10 (Naval Observatory)	11 37	−77.5	327.3	−10.5	----	18	----
		−8.0	36.8	+16.0	231	----	----
		+32.0	76.8	−8.0	34	----	----
		+34.5	79.3	+4.0	3	----	286
Sept 11 (Naval Observatory)	10 39	−60.5	331.6	−11.0	15	----	----
		+4.5	36.6	+16.0	----	231	----
		+45.0	77.1	−8.0	34	----	----
		+68.0	100.1	−10.0	----	37	317
Sept. 12 (Mount Wilson)	11 10	−48.0	330.5	−11.0	----	6	----
		+19.0	37.5	+18.0	----	303	----
		+60.0	78.5	−8.0	7	----	316
Sept. 13 (Naval Observatory)	10 31	−75.5	290.3	−12.0	----	93	----
		−39.0	326.8	−11.0	6	----	----
		+32.0	37.8	+16.0	----	185	----
		+39.0	44.8	−9.5	----	12	296
Sept. 14 (Naval Observatory)	11 24	−60.5	291.6	−11.5	----	46	----
		+45.5	37.6	+16.0	----	139	----
		+54.5	46.6	−9.0	6	----	191
Sept. 15 (Naval Observatory)	10 44	−47.5	291.7	−11.5	----	18	----
		+58.5	37.7	+16.5	----	37	55
Sept. 16 (Naval Observatory)	10 43	−33.5	292.5	−11.5	----	15	15
Sept. 17 (Naval Observatory)	10 40	−19.5	293.4	−11.5	----	12	12
Sept. 18 (Naval Observatory)	11 9	----	----	----	(1)	(1)	----
Sept. 19 (Naval Observatory)	13 11	−15.5	269.6	+16.5	3	----	----
		+3.0	288.1	−19.5	----	6	9
Sept. 20 (Naval Observatory)	10 42	−3.5	269.8	+16.5	9	----	9
Sept. 21 (Naval Observatory)	10 53	+9.5	269.5	+16.5	----	6	6
Sept. 22 (Naval Observatory)	10 41	−11.5	235.4	+18.0	----	31	31
Sept. 23 (Naval Observatory)	10 41	+2.0	235.7	+18.0	----	15	15
Sept. 24 (Naval Observatory)	10 40	−85.5	135.0	+6.0	185	----	----
		+14.5	235.0	+18.5	----	12	197
Sept. 25 (Naval Observatory)	10 40	−71.0	136.3	+6.0	170	----	----
		+28.5	235.8	+18.5	----	31	201
Sept. 26 (Naval Observatory)	10 42	−78.5	115.6	−3.0	123	----	----
		−60.0	134.1	−24.5	----	9	----
		−58.5	135.6	+6.0	139	----	----
		+41.0	235.1	+18.0	----	56	327
Sept 27 (Naval Observatory)	10 59	−64.5	116.2	−2.5	139	----	----
		−44.5	136.2	+6.0	108	----	----
		+56.0	236.7	+18.0	----	77	324
Sept. 28 (Naval Observatory)	10 49	−51.5	116.1	−2.5	123	----	----
		−31.5	136.1	+6.0	123	----	----
		+70.0	237.6	+17.5	----	25	271
Sept. 29 (Naval Observatory)	10 56	−37.5	116.8	−3.0	----	139	----
		−18.5	135.8	+6.5	123	----	262
Sept. 30 (Naval Observatory)	10 42	−24.0	117.3	−3.5	----	139	----
		−5.0	136.3	+6.0	123	----	262
Mean daily area for September							245

[1] No spots

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR SEPTEMBER, 1930 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

September, 1930	Relative numbers	September, 1930	Relative numbers	September, 1930	Relative numbers
1	d 56	11	a 39	21	8
2	a 46	12	33	22	Mc 10
3	Mc 48	13	39	23	----
4	ad 68	14	23	24	d 18
5	66	15	28	25	19
6	73	16	17	26	d 35
7	70	17	8	27	33
8	a 41	18	0	28	31
9	40	19	7	29	26
10	41	20	6	30	a 20

Mean (29 days) = 32.7.

[1] Dependent alone on observations at Zurich and its station at Arosa.
a Passage of an average-sized group through the central meridian.
c New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d= Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By RICHMOND T. ZOCH

Free-air temperatures were mostly above normal at Broken Arrow, Due West, Groesbeck, and Royal Center. At Ellendale the free-air temperatures were below normal at all levels. (See Table 1.)

Free-air relative humidities were above normal at Due West and in the upper levels at Broken Arrow, Ellendale, and Royal Center. Elsewhere they were mostly below normal.

Free-air vapor pressures were mostly above normal at Broken Arrow and Due West and in the lower levels at Groesbeck and in the upper levels at Royal Center. At Ellendale and in the upper levels at Groesbeck and in the lower levels at Royal Center they were mostly below normal.

The total precipitation for the month was below normal at Ellendale but was close to normal at the other stations.

The resultant winds were variable at the surface. (See Table 3.) At the 1,000-meter level they were southerly over the southern part of the country and westerly over the northern part. The resultants gradually changed to westerly at the 4,000-meter level with two exceptions. Over Florida they remained southerly. Over eastern Texas they were easterly, exactly opposite to the resultant winds over Oklahoma.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during September, 1930*

TEMPERATURE (° C.)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	23.2	0.0	23.6	+0.3	12.4	−2.0	24.4	+0.3	19.6	−0.6
500	22.6	+1.0	21.9	+1.1	12.4	−2.0	22.5	+0.3	18.2	0.0
1,000	20.8	+1.6	19.4	+1.2	11.7	−1.2	20.3	+0.6	15.6	+0.4
1,500	18.4	+1.6	16.2	+0.6	9.5	−1.4	18.1	+0.7	12.7	+0.4
2,000	15.7	+1.5	13.3	+0.3	7.3	−1.1	15.0	0.0	10.2	+0.5
2,500	12.4	+1.0	10.6	+0.4	4.8	−0.7	12.8	+0.2	7.4	+0.4
3,000	9.3	+0.8	7.8	+0.3	2.0	−0.5	10.4	+0.3	4.4	−0.2
4,000	3.1	+0.7	1.8	−0.6	−4.2	−1.2	6.4	+1.7	−3.4	−2.9
5,000					−9.4	−0.8				

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during September, 1930*—Continued

RELATIVE HUMIDITY (%)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	68	0	79	+9	66	−2	79	+3	70	+2
500	65	−1	78	+6	65	−1	76	0	64	−3
1,000	59	−4	74	+3	58	−2	67	−4	58	−8
1,500	54	−6	75	+3	57	+2	56	−9	59	−5
2,000	49	−6	72	+3	54	+2	55	−5	62	+3
2,500	51	0	67	+1	54	+2	44	−10	60	+4
3,000	52	+4	66	+3	54	+3	42	−8	59	+7
4,000	60	+13	64	+4	56	+10	7	−36	71	+26
5,000					54	+12				

VAPOR PRESSURE (*mb.*)

Surface	19.32	−.09	23.02	+3.04	10.10	−1.25	24.32	+1.52	16.55	+0.23
500	18.14	+0.79	20.60	+2.82	9.98	−1.12	21.27	0.97	14.24	−0.19
1,000	14.80	+0.45	16.90	+1.82	8.29	−0.80	16.34	0.13	11.24	−0.77
1,500	11.70	+0.06	14.12	+1.18	7.08	−0.20	11.88	−0.80	9.32	−0.41
2,000	9.06	+0.16	11.22	+0.70	5.88	−0.06	9.46	−0.41	7.41	−0.17
2,500	7.48	+0.81	8.71	+0.21	4.91	0.00	6.54	−1.00	5.91	+0.03
3,000	6.20	+1.19	7.12	+0.05	4.09	−0.03	5.29	−0.60	4.91	+0.46
4,000	5.18	+2.21	5.28	−0.26	2.71	+0.03			3.13	+0.76
5,000					1.63	+0.04				

TABLE 2.—*Free-air data obtained at naval air stations during September, 1930*

Altitude (meters) m. s. l.	TEMPERATURE (°C)					RELATIVE HUMIDITY (%)				
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington D. C.
Surface	24.0	25.6	20.9	16.6	20.9	74	88	67	68	74
500	22.1	23.4	17.0	13.0	19.9	66	86	74	74	64
1,000	19.7	20.8	17.1	9.3	18.6	60	81	57	71	54
2,000	13.6	14.9	15.4	4.4	13.2	63	77	31	58	60
3,000	8.1	9.4	12.2	0.6	8.2	55	72	25	50	54
4,000		2.2		−4.7	2.0		73		54	52
5,000		−3.8		−11.2			63		55	

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during September, 1930*

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Due West, S. C. (217 meters)		Ellendale N. Dak. (444 meters)		Groesbeck, Tex. (139 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (145 meters)		Spokane, Wash. (606 meters)		Modena, Utah (1,665 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	S 5 E	1.7	S 12 W	1.8	N 83 W	2.5	N 34 E	0.4	N 54 W	1.7	S 37 E	0.6	S 82 W	0.7	S 27 E	1.2	S 51 E	3.3	N 41 W	0.9	S 5 E	7.6	S 80 W	2.4
500	S 27 W	6.4	S 55 W	4.0			S 87 W	1.6	N 79 W	2.0	S 2 E	4.9			S 10 E	4.3	S 52 E	6.5	S 66 E	1.9				
1,000	S 48 W	8.2	N 85 W	6.1			S 78 W	3.2	N 77 W	3.7	S 1 E	3.4	S 80 W	3.3	S 10 E	4.0	S 46 E	6.3	S 31 E	1.3	S 16 W	1.2		
1,500	S 53 W	6.5	N 78 W	9.1			S 69 W	2.4	N 71 W	5.8	S 54 E	1.6	N 77 W	5.3	S 2 W	3.8	S 43 E	4.8	S 40 W	0.6	N 85 W	1.7		
2,000	S 73 W	4.7	N 74 W	12.2	S 89 W	3.6	S 66 W	2.7	N 74 W	7.0	N 68 E	1.7	N 75 W	6.0	S 8 W	3.5	S 33 E	4.6	S 58 W	2.6	S 78 W	2.8	S 13 W	2.2
2,500	S 87 W	4.5	N 82 W	14.2	N 85 W	5.4	S 76 W	2.9	N 69 W	9.0	N 61 E	3.9	N 81 W	5.8	S 5 W	3.3	S 30 E	4.6	S 61 W	4.8	S 74 W	3.9	S 13 W	5.9
3,000	N 76 W	4.0	N 71 W	15.1	N 87 W	6.3	S 65 W	3.2	N 67 W	9.6	N 58 E	4.4	N 89 W	5.7	S 23 W	4.0	S 19 E	3.5	S 49 W	6.0	S 79 W	4.5	S 28 W	6.7
4,000	N 58 W	3.5			N 88 W	0.7	S 76 W	3.3	N 66 W	13.6	N 19 E	4.7	N 83 W	3.7	S 30 W	4.2	S 3 W	2.5			N 71 W	3.3	S 42 W	7.1
5,000	N 62 W	4.3					S 68 W	4.9	N 77 W	11.6					S 39 W	4.5	S 52 E	1.4					S 45 W	8.0

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during September, 1930*—Continued

Altitude (meters) m. s. l.	Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (321 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,294 meters)		San Francisco, Calif. (1.7 meters)		Saulte Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)		Phoenix, Ariz. (356 meters)		Brownsville, Tex. (12 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	S 79 W	1.2	S 2 E	1.4	N 59 E	0.8	N 65 E	0.3	S 19 E	1.3	S 30 E	3.7	N 83 W	2.4	N 80 W	0.8	S 4 W	0.8	S 37 W	0.4	S 68 E	3.6	S 21 E	1.5
500	N 86 W	0.6	S 36 W	4.8	S 43 E	1.8	S 3 E	1.4	S 35 W	3.2	----------	----	S 78 W	3.1	N 88 W	4.1	N 89 W	1.3	N 77 W	3.5	S 64 E	3.4	S 3 E	6.5
1,000	N 68 W	0.8	S 64 W	4.1	S 12 E	2.8	S 56 W	4.9	S 78 W	4.4	----------	----	S 61 W	2.4	N 87 W	7.8	N 43 W	1.2	N 77 W	4.5	S 4 E	1.6	S 5 E	6.8
1,500	S 80 E	0.6	S 74 W	2.9	S 6 E	3.6	S 74 W	5.9	S 83 W	6.7	S 19 E	4.6	S 1 E	2.0	N 79 W	9.1	N 27 W	2.1	N 83 W	5.7	S 27 W	2.4	S 15 E	5.2
2,000	S 53 E	0.7	N 63 W	1.3	S 7 E	3.6	S 88 W	7.6	N 86 W	8.8	S 3 W	4.2	S 16 E	1.7	N 79 W	9.5	N 1 E	1.0	N 87 W	8.0	S 22 W	3.7	S 42 E	1.7
2,500	S 46 W	0.7	N 76 W	1.3	S 11 W	2.7	N 83 W	8.1	N 78 W	10.6	S 33 W	3.9	S 12 E	2.3	N 71 W	11.4	----------	----	N 86 W	10.3	S 24 W	4.9	N 60 E	1.4
3,000	S 19 W	1.8	N 57 W	2.0	S 34 W	1.6	N 76 W	9.7	N 84 W	10.4	S 57 W	4.6	S 17 W	2.5	N 65 W	12.7	----------	----	S 87 W	10.8	S 23 W	6.4	S 72 E	1.7
4,000	S 70 W	2.4	----------	----	N 81 W	2.0	N 66 W	7.6	N 75 W	9.1	S 67 W	6.2	S 38 W	4.2	----------	----	----------	----	N 89 W	12.6	----------	----	N 53 W	1.2
5,000	----------	----	----------	----	N 85 W	4.4	----------	----	----------	----	S 73 W	6.9	N 86 W	5.4	----------	----	----------	----	----------	----	----------	----	----------	----

TABLE 4.—*Observations by means of kites, captive and limited-height sounding balloons during September, 1930*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	2,721	2,937	3,296	2,507	2,653
Maximum altitude (meters), m. s. l., reached and date	[1] 4,141	[2] 4,264	[3] 8,384	[4] 4,024	[5] 4,580
Number of flights made	29	28	31	21	29
Number of days on which flights were made	29	28	30	20	26

[1] 15th. [2] 15th. [3] 29th.; limited-height sounding balloon observation. [4] 23d. [5] 5th.

In addition to the above there were approximately 130 pilot balloon observations made daily at 56 Weather Bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

September was warmer than normal throughout the eastern half of the country, especially from the Carolinas to the New England States where the monthly means were from 4° to 8° above the normal, while they were near the normal in most sections from the Rocky Mountains westward; however, freezing weather occurred in the Northwest during the latter part of the month.

The droughty conditions that had prevailed in most sections were relieved early in the month over much of the Great Plains and the Ohio Valley, and toward the middle of the month throughout most sections from the Rocky to the Appalachian Mountains, although the upper Mississippi Valley and other north central areas continued dry, and the drought continued in the Middle Atlantic area. The latter part of the month brought additional rainfall in most sections except over much of the area from northern North Carolina to southern Pennsylvania, where the severe drought continued.

TEMPERATURE

The noteworthy tendency to abnormally high temperatures continued, especially in the northeastern portion. Since January, no month has averaged cooler than normal in the northern border strip from the Rocky Mountains to the middle of the Lake region, while in nearly every State east of the Plains at least six of the last eight months have been hotter than normal.

The first decade was mainly hot, expecially in the Atlantic and Gulf States, the central valleys and the far Northwest, but was slightly cooler than normal in most of the Lake region and the north-central portion, also in many interior districts of Oregon and California. The middle decade and the first portion of the last decade were warm in most sections, though much of the far West and portions of the Gulf States were colder than normal, at least during part of this period. The final week was cool, save in the eastern third and the central valleys; the Atlantic States had unseasonably warm weather till the 27th or 28th, when a change to cooler reached them.

The temperature of the month averaged above normal practically everywhere save in California and the southern plateau region and in most of North Dakota. From North Carolina northeastward the month was much warmer than normal, being at many places the hottest September since 1881, and at a few the hottest ever recorded.

The highest readings were noted usually during the first four days in the eastern third of the country and in the far West. In the middle portion of the country they occurred, as a rule, at various later dates, but seldom after the 18th. For the most part, previous September records, especially those made in 1881 or 1925, were not exceeded.

The lowest marks were usually reached during the final week, though in some States along the northern border they occurred before the middle of the month. There were but few States where they closely approached the previous records.

PRECIPITATION

Considerably more than half of the country received less than the normal September rainfall, yet important regions had partial or complete relief from the serious drought of earlier months. From Kansas, Missouri, and the lower Ohio Valley southeastward liberal rainfall was the rule, with considerable benefit to late crops and pasturage, particularly as the principal rains in this area occurred before the middle of the month, save near the east Gulf and south Atlantic coasts, where they were mostly very heavy, falling chiefly after the middle of the month.

On the other hand, the Southwest, the northern Plains and the Lake region received mainly less rain than normal. In North Dakota, Oklahoma, and Texas, this was the fourth dry month in succession, and in most of the Lake region the third.

Dryness in September was particularly notable from the upper Ohio Valley and North Carolina northeastward. A very large part of this section received less than half of the September normal and considerable districts less than a quarter. Furthermore, for much of the area it was the seventh or eighth or sometimes even the tenth dry month in succession, while in Maryland and Virginia no month since June has brought even half of the normal rainfall. Naturally water supplies have been greatly depleted and pastures are in wretched condition in the drier portions.

The far West showed some diversity as to rainfall, but the middle and northern portions of the plateau region and most of Oregon received somewhat more rainfall than normal.

SNOWFALL

During the final week the Black Hills region received more snow than usually occurs there in September. Many elevated portions of the far West had light to moderate falls, chiefly during the last week, a few stations reporting total amounts in excess of a foot.

SUNSHINE AND RELATIVE HUMIDITY

Much cloudy weather prevailed in the Ohio and southern Mississippi Valleys and to the southeastward, in the northern portions of the New England and Lake region, the far Northwest and northern half of the Pacific coast region. Elsewhere, rather a large amount of sunshine prevailed, although throughout the more arid regions of the Southwest less than the average for September was received. The relative humidity was generally below the normal over much of the country, as would be expected because of the deficiency of precipitation for the month in many sections; however, throughout the Southeast, where more than the normal precipitation was received, the humidities were without exception above normal.

SEVERE LOCAL STORMS, SEPTEMBER, 1930

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Binghamton, N. Y., and vicinity.	1	4 p. m.		1	$125,000	Wind and rain	Power lines, buildings, trees, and crops damaged.	Official, U. S. Weather Bureau.
Dane County, Wis. (northern).	1	P. m.			250,000	Hail	Severe damage to tobacco and corn crops	Do.
Harrisburg, Pa., and vicinity.	1	do			20,000	Electrical	Several barns and contents destroyed	Do.
Selinsgrove, Pa	1	do			10,000	do	Barn and contents destroyed	Do.
York, Pa. (near)	1	do			10,000	do	do	Do.
Canon City, Colo	2					Hail and rain	All fruits, flowers, and vegetables practically destroyed; basements flooded; highways and railroads damaged.	Do.
Eslie, Nebr	3	5 p. m.	2 mi.		30,000	Hail	Severe crop injury in places; livestock hurt; buildings damaged; path 25 miles long.	Do.
Sutherland, Nebr	3	do	3 mi.		25,000	do	Crops and roofs badly damaged	Do.
Cimarron, N. Mex., and vicinity.	4	2 p. m.	440		1,500	do	Considerable damage to roofs, autos, and crops	Do.
Russell County, Kans	4	4 p. m.			25,000	do	do	Do.
El Dorado and Smackover, Ark.	4				17,000	Wind	No details reported	Do.
Sugarite, N. Mex., and vicinity.	5	1:15-2 p. m.			5,000	do	Unharvested wheat and oats in path complete loss.	Do.
Elk Creek, Colo	5					Hail	No details reported	Do.
Butte, Nebr. (2 miles south)	6	10 p. m.	4 mi			Hail and rain	Considerable damage in small areas; path 18 miles long.	Do.
Florence, Colo	6	P. m.			250,000	Hail	Matured crops practically total loss; 200 carloads of vegetables ruined.	Do.
Powder River and Wibaux Counties, Mont.	6					do	Chief damage to crops	Do.
Plymouth and Woodbury Counties, Iowa.	7	P. m.			800,000	Hail and wind	Character of damage not reported	Do.
Carter County, Mont	7					Hail	Crops injured	Do.
Norwood, Colo	7					do	No details reported	Do.
Cotton County, Okla. (northeast).	8	4 p. m.	3 mi.		51,000	do	Heavy crop damage; 1,500 chickens and turkeys killed; path 5 miles long.	Do.
Mountain Home, Ark	8				4,000	Hail and wind	Character of damage not reported	Do.
Plaza, Wash	8					Electrical	Practically 73,000 bushels of grain destroyed	Do.
Tampa, Fla., and vicinity	8-9				75,000	Wind and rain	Damage to crops, highways and bridges chiefly by torrential rains.	Do.
Lampasas, Tex. (near)	9	4:30 p. m.	400		1,000	Tornado	Buildings damaged	Do.
Fallon County, Mont	11					Hail	260 acres of flax ruined	Do.
Dickinson and Osceola Counties, Iowa.	12	3-4 p. m.			6,500	Wind and hail	Crops damaged	Do.
Carteret County, N. C	12					Wind	Character of damage not reported	Do.
Raymondsville, Mo	12				2,000	Wind and rain	Small buildings and haystacks blown down	Do.
Sedan and Peru, Kans. (vicinity of).	12		2 mi.		5,000	Wind	Oil-pumping station and barns wrecked; trees uprooted; path 20 miles long.	Do.
Rush County, Kans	13	P. m.	8 mi.			Wind and hail	Many farm buildings blown down	Do.
Auburn, Nebr	14	4:30 a. m.	1.5 mi.		10,000	Hail	Corn injured; much glass broken; minor roof damage; path 5 miles long.	Do.
Terre Haute, Ind	14	A. m.			10,000	Wind	Roof blown from brick and clay works	Do.
Bellview, N. Mex. (near)	14	Noon-1 p. m.	3-5 mi.			Hail	Crops total loss for 3 miles of path. Path 15 miles long.	Do.
Logan, N. Mex., and vicinity.	14	1-1:20 p. m.			5,000	do	Crops destroyed or injured	Do.
Plymouth County, Iowa	14	1:30 p. m.			5,000	Wind and hail	Crops and livestock injured	Do.
Fairbury, Nebr. (4 miles south).	14	2 p. m.	2.5 mi.		2,000	Hail	Late melon and garden crops damaged; path 11 miles long.	Do.
Pratt to Isabel, Kans	14	3:30 p. m.	8 mi.			do	Crops, roofs, windows, and automobiles damaged; poultry killed; path 25 miles long.	Do.
Freeport, Kans. (4 miles southwest).	14	5:15 p. m.	50		12,000	Tornado	Buildings on 2 farms demolished; farm implements damaged; livestock injured; path 1 mile long.	Do.

[1] "Mi." signifies miles instead of yards.

Severe local storms, September, 1930—Continued

The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Stillwater, Okla.	14	8 p. m.	5 mi.		3,000	Wind	Some crop and property damage	Official, U. S. Weather Bureau.
Fort Smith, Ark. (1 mile northwest).	14	10 p. m.			100,000	Wind and rain	Many buildings unroofed; some flimsy structures demolished; trees uprooted.	Do.
Mount Vernon, Ill.	14	10:45 p. m.	200-440		500,000	Tornado	Streets blocked by fallen trees, poles, and wires; a number of houses unroofed or otherwise damaged; 12 persons injured; path 1.5 miles long.	Do.
Belle Rive and Dahlgren, Ill., and vicinity.	14	11 p. m.			50,000	Wind	Several buildings wrecked or badly damaged	Do.
Browning, Mo.	14	do			2,000	do	Roofs, chimneys, and trees damaged	Do.
Lexington, Ky.	14					Wind	Trees and wires blown down	Do.
Sanborn, Ind. (near)	14					Electrical	2 barns and contents burned	Do.
Rushville, Huntsville, and Vermont, Ill., and vicinity.	14					Wind and electrical.	A number of buildings struck; house and 3 barns burned; 50 poles blown down.	Do.
Cleveland, Miss. (2 miles north).	15	3 a. m.	300	1	300	Probably tornado	Minor property damage; 1 person injured	Do.
Philadelphia, Pa. (Germantown section).	16	7 p. m.	50		2,500	Tornado	A few buildings damaged; trees uprooted	Do.
Clarkelen, Wyo. (near)	17	9:15-9:25 p. m.	1,760		2,200	Probably tornado	Alfalfa and buildings damaged	Do.
Monroe County, Iowa	18	3 p. m.	33-50		9,500	Wind and tornado	Character of damage not reported; path 8 miles long.	Do.
Cerro Gordo and Dickinson Counties, Iowa.	19					Wind and hail	Corn damaged	Do.
Fort Wayne, Ind.	22				67,000	Electrical	Lumber yard and small mill destroyed by fire	Do.
Miami, N. Mex., and vicinity.	22					Wind	Haystacks overturned; shocked beans scattered; outbuildings wrecked; orchards injured.	Do.
Port Arthur, Tex.	23	5 a. m.	100		8,000	Probably tornado	Buildings and household goods damaged; 3 persons injured.	Do.
Anna, Ill.	24	11 a. m.	16-33		10,000	Small tornado	Property damaged at intervals over path 2.5 miles long.	Do.
Smith Center, Kans. (near)	25	3 p. m.				Wind and hail	Number of small buildings wrecked; some damage to crops.	Do.
Lee County, Iowa	25	3:30-4 p. m	880	2	47,000	Wind, hail and tornado.	Path 6 miles long; character of damage not reported.	Do.
Lee County, Iowa	25	do	880		3,000	do	Path 2 miles long; character of damage not reported.	Do.
Monroe County, Iowa	25	4-4:30 p. m.			17,300	do	Path 14 miles long. No details reported	Do.
Montgomery County, Iowa	25	4:30 p. m.	27		1,000	Tornado	Path 4 miles long. No details reported	Do.
Lawrence, Kans., and vicinity.	25	4:50 - 5:25 p. m.				Wind	Damage to buildings on State University campus.	Do.
Fort Scott, Kans. (4 miles east) to Richards, Mo. (near).	25	5 p. m.		2	53,760	Probably tornado	9 freight cars blown from train; other property damage.	Do.
Clinton County, Iowa	25	5:45 p. m.			51,000	Tornado and wind	Character of damage not reported	Do.
Monmouth, Ill., and vicinity.	25	do			10,000	Wind	Buildings, poles and trees damaged	Do.
Dodge City, Kans.	25				9,000	do	Great Southwest Fair suffers considerable loss	Do.
Grand Haven, Mich.	25					Wind squall	Roof of refrigerator plant partially destroyed	Do.
Iowa (28 counties)	25					Wind and hail	Extensive damage to buildings and crops over wide area.	Do.
Siloam Springs, Ark.	25				35,000	Wind	No details reported	Do.
Springfield, Ill.	25				8,000	do	Trees blown down caused minor damage to buildings.	Do.
Tulsa, Okmulgee, and Cherokee Counties, Okla.	25				51,900	Three wind storms.	Crops and residences damaged; 14 tents at fairgrounds destroyed; trees uprooted.	Do.
Wyoming, Ill., and vicinity.	25				10,000	Wind	Buildings damaged	Do.
Iowa (13 counties)	25-26					Wind and hail	Overhead wires damaged; crops prostrated	Do.
Wisconsin (southeast) and southern Lake Michigan.	25-26			10		Wind and small tornado.	Hangar damaged; small buildings blown over; 3 vessels lost.	Do.
Adair, Butler, Clayton, Greene, Hancock, and Pocahontas Counties, Iowa.	26					Wind and hail	Damage chiefly to crops	Do.
Ganges, Mich.	26					Wind	Three-fourths of winter apples and pears blown off.	Do.
Indiana	26					do	Damage confined chiefly to trees and wires	Do.
Ludington, Mich.	26					do	Wires and cables blown down; windows broken; trees uprooted; heavy loss to apple crop.	Do.
Tuscola County, Mich. (central).	26		50		12,000	Probably tornado	Number of buildings wrecked and plate glass windows broken in village of Caro. Path 1 mile.	Do.
Buffalo, N. Y., and vicinity.	26-27					Wind	Wires blown down; trees uprooted; some damage on lake front.	Do.
Greene County, Iowa	28-29				3,500	Wind and hail	Crops damaged	Do.

RIVERS AND FLOODS

By R. E. SPENCER

No floods occurred in the principal rivers of the United States during September, except that the Trinity River remained above the flood stage of 25 feet at Dallas, Tex., from September 1 to 27. This high (artificial) stage was an effect of a temporary dam constructed to aid levee work below that city; the maximum reached was 27.3 feet on September 1.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The outstanding feature of the month was the tropical disturbance generally known as the "Santo Domingo hurricane," that is fully described elsewhere in the REVIEW. While this storm was extremely severe during the period from the 1st to 3d and on the 13th and 14th the diameter of the storm area was unusually small, and in consequence comparatively few reports were received from vessels involved. Among the vessels heavily involved was the American S. S. *Coamo*, the experience of which is narrated elsewhere in the REVIEW.

Charts VIII to X cover the period from the 1st to 3d, inclusive, and besides giving an idea of the conditions in tropical waters, also show the state of the weather encountered by the French airplane *Question Mark* during the nonstop flight from Paris to New York. The *Question Mark* left France on the 1st and arrived at Curtis Field on the evening of the 2d. In connection with this flight it is interesting to note that on the 1st the normal pressure distribution over the eastern section of the ocean was reversed. The barometric reading at Horta was 29.80 inches and at stations in the British Isles 30.37 inches. This unusual condition was responsible for strong easterly winds, reaching in some cases gale force over the eastern section of the steamer lanes. On the 2d, light to moderate winds were the rule over the greater part of the ocean, and there was considerable fog west of the fortieth meridian.

Taking the ocean as a whole, the number of days with gales was somewhat below the normal, as not more than four were reported from any 5° square. Two of the disturbances were of exceptional severity, however; the "Santo Domingo hurricane" and the storm that will be described later and which caused an immense amount of damage on the French coast on the 19th.

The number of days on which fog was reported in different localities is as follows: Over the Grand Banks, from 11 to 13 days; between the fortieth and forty-fifth parallels and sixtieth and seventieth meridians, from 14 to 15 days; over the steamer lanes east of the forty-fifth meridian, from 2 to 6 days; in the Gulf of Mexico, 2 days.

Barometric data for several island and coast stations are given in the following table:

TABLE 1.—*Averages, departures and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian)—North Atlantic Ocean, September, 1930*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.89	(1)	30.21	30th	29.52	27th.
Belle Isle, Newfoundland	29.77	[2] −0.13	30.16	21st	29.26	24th.
Halifax, Nova Scotia	29.95	[2] −0.10	30.34	1st	29.74	28th.
Nantucket	29.99	[2] −0.09	30.34	1st	29.72	27th.
Hatteras	30.04	[2] −0.04	30.30	1st	29.86	27th.
Key West	29.97	[2] +0.01	30.10	24th	29.88	6th.[4]
New Orleans	29.98	[2] −0.02	30.16	1st	29.90	15th.[4]
Cape Gracias, Nicaragua	29.85	[2] −0.06	29.92	9th [4]	29.80	7th.[4]
Turks Island	30.03	[2] +0.05	30.12	24th	29.90	10th.
Bermuda	30.09	[2] +0.01	30.32	1st	29.94	27th.[4]
Horta, Azores	30.08	[2] −0.08	30.26	11th	29.82	29th.
Lerwick, Shetland Islands	29.94	[2] +0.10	30.36	27th [4]	29.29	20th.
Valencia, Ireland	29.93	[2] −0.06	30.33	1st	28.58	19th.
London	29.95	[2] −0.05	30.38	2d [4]	29.25	20th.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other date or dates.

As stated previously, the conditions from the 1st to 3d are shown on Charts VIII to X, inclusive. On the 4th the tropical disturbance was over the Windward Passage, while over the greater part of the ocean moderate weather prevailed from this date until the 12th. Two disturbances of apparently local nature were reported in the Caribbean Sea on the 6th and 8th, respectively, as shown by notes at the end of this article.

On the 13th the position of the tropical storm is shown on the track as near 37° N., 72° W. On the same day Belle Isle was a short distance west of the center of a well-developed LOW, and another depression was over the British Isles, both being accompanied by westerly to northwesterly gales. On the 14th a LOW, central near 38° N., 64° W., was probably a continuation of the tropical storm; on the 15th the center was apparently near 36° N., 53° W., and on the 16th somewhere near 37° N., although its position on the latter two dates was uncertain, especially on the 16th.

On the 14th the northern LOW was central near 50° N., 38° W., while moderate to strong gales prevailed over the greater part of the steamer lanes, between the 20th and 50th meridians; it then evidently recurved toward the north, as on the 15th the center was near 55° N., 33° W., while the storm area had contracted and now covered the region between the center and forty-fifth parallel, and the thirtieth and fortieth meridians.

Charts XI to XIII show the conditions from the 17th to 19th, inclusive, and give an idea of the intensity and extent of the disturbance that reached its climax on the 19th. According to press reports this was the worst storm in many years off the coast of France, and was responsible for large loss of life and property, especially among the fishermen of Brittany. On the 20th the center was near the mouth of the River Tyne on the east coast of England, and while the storm area had decreased somewhat in extent, winds of force 10 and 11 were still encountered as far south as the forty-fifth parallel.

On the 20th a second depression was over Newfoundland that moved rapidly northeastward, and on the 21st moderate to strong gales prevailed over a limited area between the thirty-fifth and fiftieth meridians. This LOW was closely followed by a third that on the 23d was central near St. Johns, Newfoundland, and reached its greatest intensity on the 30th when central near 43° N., 20° W., as on this date winds of force 7 to 10 were reported between the thirty-fifth and forty-fifth parallels. From the 26th to 29th moderate gales occurred over the eastern sections of the steamer lanes, and on the 27th a number of stations on the British Isles reported northerly winds, force 7, with comparatively high barometric readings.

Notes.—Bogota, American steamship, captain and observer, H. M. Davis, New York to Haiti. September 4, between Castle Island and northwest coast of Haiti. Heavy wind all day with squalls reaching gale force with rain and heavy sea; both diminishing as ship approached coast of Haiti at night.

On the 6th a Pan American airplane between St. Vincent and St. Lucia reported at noon: Gale 100 miles an hour, heavy rain, no visibility. At St. Lucia, barometer 29.94 inches, wind NE., 3. German S. S. *Rhodopis*, at 8 a. m. on the 8th in 15° 45′ N., 68° 40′ W., heavy squalls, force 10 with heavy rain from SE., confused sea up to 10 a. m., afterwards becoming east and diminishing.

American S. S. *Dorothy Luckenback*, Capt. H. A. Lewald; observer, I. Lysted, 3d officer; from San Pedro to Philadelphia, September 4, 6.15 p. m., 19° 03′ N., 74° 26′ W. Observed a big waterspout 1,200 feet high. Barometer 29.78, wind E., 4. Diameter very large, circular motion not very distinct, traveling northwestward.

OCEAN GALES AND STORMS, SEPTEMBER, 1930

Vessel	Voyage From—	Voyage To—	Position at time of lowest barometer Latitude	Position at time of lowest barometer Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
K. R. Kingsbury, Am. S. S.	New York	Canal Zone	21 21 N	74 08 W	Sept. 4	5 p., 4	Sept. 4	29.89	E	SE, 7	SE	ESE, 8	E-SE-SSE.
Bannack, Am. S. S.	Cork	New York	47 31 N	49 52 W	Sept. 6	5 a., 6	Sept. 6	29.69	WSW	W, 7	SW	W, 8	WSW-W.
W. C. Teagle, Am. S. S.	New York	Aransas Pass	28 46 N	78 30 W	Sept. 10	6 p., 10	Sept. 11	29.86	S	S, —	SW	ESE, 8	
Liberty Glo, Am. S. S.	Bremen	Wilmington, N. C.	35 30 N	75 10 W	Sept. 12	3 p., 12	Sept, 12	29.05	E	E, —	NW	—, 12	E-SE.
President Wilson, Am. S. S.	New York	Canal Zone	35 06 N	75 06 W	do	8 p., 12	do	29.13	SE	—, 12	W	SE, 12	SE-W.
Quaker City, Am. S. S.	Dundee	Philadelphia	49 28 N	47 55 W	do	10 p., 12	Sept. 13	29.30	SSW	—, 8	W	—, 9	
Independence Hall, Am. S. S.	New York	Havre	50 10 N	18 00 W	Sept. 13	2 a., 13	Sept. 14	29.91	NW	NW, 8	NW	NW, 9	Steady.
Okeania, Gr. S. S.	Gibraltar	Baltimore	36 28 N	60 35 W	Sept. 14	4 p., 14	do	29.14	S	S, 10	N	S, 10	S-W-N.
Nessian, Br. S. S.	Swansea	Montreal	53 30 N	26 08 W	do	4 a., 14	Sept. 16	29.62	SE	SE, 9	SW	SSE, 9	SSE-SW.
Naples Maru, Jap. S. S.	Newcastle on Tyne.	Savannah	39 11 N	55 07 W	do	8 a., 15	Sept. 15	29.62	E	ENE, 8	N	—, 8	
New York, Ger. S. S.	Cherbourg	New York	45 34 N	42 08 W	Sept. 17	8 a., 17	Sept. 17	29.67	S	W, 8	N	NW, 9	S-W-NW.
Sarcoxie, Am. S. S.	Bordeaux	do	44 48 N	23 40 W	do	8 a., 18	Sept. 23	29.49	S	W, 7	W	NW, 10	
Ambridge, Am. S. S.	Antwerp	do	50 16 N	12 12 W	Sept. 18	Noon, 18	Sept. 20	28.60	NNW	NNW, —	WNW	NNW, 12	S-SE-NNW.
Reventazon, Br. S. S.	Hull	Santa Marta	46 50 N	9 40 W	do	Mdt., 18	do	29.24	SSE	SSE, 8	NNW	SW, 10	SSE-SW-WNW.
Samala, Br. S. S.	Liverpool	Jamaica	49 05 N	13 20 W	Sept. 19	5 a., 19	do	28.64	S	S, 9	NW	WNW, 11	
West Cobalt, Am. S. S.	Dundee	New Orleans	47 35 N	6 55 W	Sept. 17	2 a., 19	do	29.24	SW	WSW, 11	NW	—, 11	S-W-NW.
Arden, Am. S. S.	Black Sea	New York	42 58 N	43 00 W	do	3 a., 20	Sept. 21	29.70	S	SW, 6	N	NW, 9	
Saco, Am. S. S.	Rotterdam	do	51 24 N	2 08 E	Sept. 20	4 p., 20	do	29.28	SW	SW, 9	W	WSW, 10	SW-WSW.
Ambridge, Am. S. S.	Antwerp	do	49 05 N	32 08 W	Sept. 22	10 a., 22	Sept. 24	29.66	NW	NW, 7	W	—, 10	Steady.
Cuba, Fr. S. S.	Habana	Corunna	42 30 N	44 30 W	Sept. 23		Sept. 25	29.66	S	SSW, 8	SSE	SSW, 9	
Emile Francqui, Belg. S. S.	New York	Antwerp	45 48 N	39 54 W	Sept. 25	Noon, 25	Sept. 27	29.53	SSE	Var. 2	SSE	SSE, 9	Steady.
Yselhaven, Du. S. S.	Bremen	Norfolk	48 32 N	32 23 W	Sept, 27	11 a., 28	Sept. 28	29.61	SE	Var. 2	Var	SE, 9	
Western Queen, Am. S. S.	Bremerhaven	Freeport	42 50 N	23 10 W	Sept. 29	2 p., 29	Sept. 29	29.34	WSW	NW, 9	NE	NW, 9	WSW-NE.
Bogota, Am. S. S.	New York	Haiti	27 50 N	74 17 W	Sept. 30	3 p., 30	Oct. 1	29.92	SW	SW, 6	SW	—, 9	
Nemaha, Am. S. S.	Holland	Mobile	44 14 N	22 05 W	do	2 a., 30	do	29.36	NE	NNE, 11	N	—, 11	Steady.
Grete, Ger. S. S.	Hamburg	Savannah	43 34 N	21 26 W	Sept. 29	Noon, 30	do	29.39	ESE	N, 10	NNW	—, 11	NNE-NNW.
NORTH PACIFIC OCEAN													
Pres. Harrison, Am. S. S.	San Francisco	Kobe	29 14 N	177 50 W	Sept. 2	11 a., 2	Sept. 2	29.05	ESE	NE, 11	NNW	NE 11	ESE-NE-N.
Do	do	do	33 16 N	152 47 E	Sept. 8	4 a., 8	Sept. 8	29.38	SE	S, 12	SSW	SSW, 12	SE-S-SW.
San Diego Maru, Jap. M. S.	Kobe	San Francisco	41 50 N	169 35 W	Sept. 2	2 a., 4	Sept. 4	28.82	E	NW, 8	SW	W, 10	N-SW.
Tamaha, Br. S. S.	San Pedro	Dairen	46 54 N	166 20 W	Sept. 3	8 p., 4	Sept. 5	28.35	NE	S, 12	WSW	S, 12	SE-S.
Iwatesan Maru, Jap. S. S.	Yokohama	San Francisco	45 00 N	168 00 W	do	7 a., 4	do	28.12	NE	NW, 4	WSW	SW, 11	NNE-NW.
Satanta, Br. S. S.	Swatow	San Pedro	45 09 N	167 50 W	do	7 a., 4	do	28.23	ENE	ESE, 10	S	S, 12	E-ESE-SE.
Golden Star, Am. S. S.	Shanghai	San Francisco	48 35 N	173 15 W	Sept. 4	7 p., 5	do	29 22	NE	N, 11	W	NNW, 11	NE-N-NW.
Akagisan Maru, Jap. M. S.	Olympia	Yokahama	51 06 N	175 27 W	do	5 p., 4	Sept. 6	29.63	N	NNW, 8	NW	N, 9	N-NW.
Olympia Maru, Jap. M. S.	Yokohama	Seattle	39 16 N	149 13 E	Sept. 8	Noon, 9	Sept. 9	28.98	NW	WSW, 9	SW	WSW, 9	Steady.
Ayaha Maru, Jap. S. S.	Miike	Victoria	40 45 N	150 50 E	do	7 p., 8	do	29.23	ENE	ENE, 11	E	ENE, 11	2 pts.
Mojave, Am. S. S.	Yokohama	San Pedro	36 56 N	146 12 E	Sept. 6	3 a., 8	Sept. 10	29.42	NE	NNE, 10	W	W, 11	NE-N.
Do	do	do	44 25 N	173 02 W	Sept. 14	6 p., 16	Sept. 18	29.88	NE	N, 10	NNW	NNE, 10	NE-NNE.
Ayaha Maru, Jap. S. S.	Miike	Victoria	50 35 N	158 52 W	Sept. 17	4 a., 18	do	29.13	NNE	NW, 10	NW	N, 10	1 pt.
Tecumseh, Br. S. S.	Nagasaki	San Pedro	46 29 N	148 09 W	do	2 a., 18	do	29.52	S	S, 8	SSW	S, 8	Steady.
Hakonesan Maru, Jap. M. S.	Portland	Yokohama	49 34 N	174 18 E	Sept. 20	6 p., 20	Sept. 21	29.48	SSE	SSW, 8	WSW	S, 8	S-SSW.
Do	do	do	41 55 N	150 30 E	Sept. 23	8 a., 24	Sept. 24	29.83	SSE	SSE, 8	N	SSE, 8	SSE-NW.
Golden Dragon, Am. S. S.	San Francisco	Otaru	50 40 N	169 50 W	Sept. 20	4 p., 20	Sept. 21	29.50	SSE	SSE, 8	NW	SSE, 9	SW-SSE.
Do	do	do	50 13 N	179 30 W	Sept. 23	6 a., 23	Sept. 24	29.73	NNE	NE, 8	ENE	NE, 8	2 pts.
Shabonee, Br. S. S.	Shanghai	San Pedro	39 18 N	173 10 E	Sept. 25	4 p., 25	Sept. 25	29.64	ESE	E, 10	SE	E, 10	NE-SE.
Pres. Grant, Am. S. S.	Seattle	Yokohama	52 21 N	163 10 W	Sept. 24	6 p., 24	do	29.63	W	W, 6	NW	NW, 9	W-NW.
Shiraha Maru, Jap. S. S.	Miike	Puget Sound	50 40 N	145 20 W	Sept. 25	10 p., 25	Sept. 27	28.74	SSE	S, —	W	NW, 10	SW-S-NW.
San Marcos, Am. S. S.	San Pedro	Balboa	17 43 N	102 42 W	Sept. 26	5 a., 26	Sept. 26	29.88	NNW	ESE, —	SW	ESE, 9	NNW-ESE.
Starr, Am. S. S.	Seward	Bristol Bay	59 36 N	144 03 W	Sept. 25	8 p., 26	Sept. 28	29.06	NE	NE, —	SE	NE, 9	
Admiral Watson, Am. S. S.	Seattle	Kodiak	59 38 N	142 03 W	Sept. 29	6 a., 29	Sept. 30	29.02	E	N, —	E	N, 9	E-NE-N.
INDIAN OCEAN													
Brookwood, Br. S. S.	Mauritius	Port Kembla	36 54 S	122 19 E	Sept. 14	Noon, 15	Sept. 15	29.38	NNE	NNW, 8	NNW	NNE, 9	NNW-WNW.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

The condition of unusually high atmospheric pressure which prevailed over the Aleutian Islands and the Bering Sea during July and August, continued through the greater part of September. Although the averages of the barometric readings at St. Paul and at Dutch Harbor were no higher than 29.99 and 29.95 inches, respectively, their plus departures from the normal were considerable, as shown in the table. The Aleutian LOW was central at or near Kodiak, where the average pressure for the month was 29.76 inches, but comparatively low barometer prevailed thence south-southwestward into the Tropics. Midway Island, generally in the high-pressure belt in September, now had an average reading of 29.92 inches, which was 0.15 inch below the normal. Thus, nearly north and south in midocean, lay an unusual cyclonic belt, with anticyclonic regions on either side—on the one hand stretching nearly to the American coast; and on the other, to about the one hundred and fifty-fifth meridian of east longitude.

The accompanying table gives the principal barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, September, 1930*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [3]	29.98	----------	30.44	25th	29.40	29th.[6]
Dutch Harbor [2] [3]	29.95	+0.19	30.40	25th	29.18	5th.
St. Paul [2] [3]	29.99	+0.29	30.42	2d	29.58	8th.
Kodiak [3]	29.76	+0.06	30.18	5th	29.26	25th.
Midway Island [2] [3]	29.92	−0.15	30.14	7th	29.53	2d.
Honolulu [4]	29.96	−0.04	30.04	11th	29.85	19th.
Juneau [4]	29.91	−0.01	30.31	6th	29.14	26th.
Tatoosh Island [4] [5]	29.99	−0.02	30.18	19th	29.64	23d.
San Francisco [4] [5]	29.96	+0.02	30.16	25th	29.78	6th.
San Diego [4] [5]	29.93	+0.05	30.09	25th	29.77	27th.

[1] For 26 days.
[2] For 29 days.
[3] P. m. observations only.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.
[6] Also on 30th.

The mid-Pacific trough of low pressure was the scene of considerable storm activity, and here during the early part of the month occurred one of the severest September storms for the region in recent years. The cyclone was probably of tropical origin, with the initial disturbance occurring very close to the one hundred and eightieth meridian. It was first experienced on September 1 some 300 or 400 miles south-southwest of Midway Island, where the American steamer *Steel Scientist* ran into its moderate southerly gales, with barometer even at that time depressed to 29.56 inches. On the 2d, just north of Midway, the storm had perhaps already developed hurricane intensity, since the steamer *President Harrison* steamed at 11 a. m. into a full northeast storm wind, barometer at 29.05, in 29° 14′ N., 177° 50′ W. By the 3d the cyclone was central at about 40° N., 170° W. Late in that day several vessels entered the outer storm region, where they met with strong to whole gales. But it was not until the 4th that the great fury of the cyclone was actually encountered. On this day and on the 5th hurricane velocities were engaged with over an extensive area south of the central and eastern Aleutians. The minimum barometer reading reported was 28.12 inches, read on board the steamer *Iwatesan Maru* in 45° N., 168° W., at 7 a. m. of the 4th. The storm entered the Bering Sea on the 5th and thereafter lost energy, becoming a shallow depression which was lost in the Arctic Ocean on the 7th.

The second progressive mid-ocean cyclone of the month probably developed north of Midway Island on the 15th or 16th, and on the latter date moderate to fresh northerly gales were reported in the vicinity. The storm moved at first with great rapidity toward the northeast, but on the 17th curved into north with lessened speed. During the 18th and 19th it crossed the western part of the Gulf of Alaska, causing fresh to whole gales on the 18th along more than a thousand miles of the upper trans-Pacific steamer route. After entering Alaska, the disturbance turned rapidly eastward into the Canadian Northwest.

From the 24th until the end of September disturbed weather prevailed over the Gulf of Alaska, and fresh to strong gales were experienced on the 26th to 29th in the waters between Sitka and Valdez, and fresh to whole gales on the 25th to 27th over the southern part of the Gulf.

Generally quiet weather prevailed for a long distance west of the coast of the United States, and few extratropical gales were reported as occurring between the western Aleutians and Japan.

The weather was unusually serene for the month in tropical American waters. A brief gale of force 9 from the east-southeast, experienced during a severe thunder squall off the coast between Acapulco and Manzanillo on the 26th, and a moderate south gale in the lower part of the Bay of Panama on the 2d, were the only gale winds reported.

At least one violent typhoon occurred in the Asiatic Tropics. It was first noted east of Guam, traveling westward, on the 3d. On the 7th, after curving through north into northeast, it arrived east of the Ogasawara Islands considerably intensified. It then moved northward again and on the 8th and 9th was central at some distance east of Hondo. On these dates it was unquestionably a violent typhoon, but on the 8th, specifically, reporting vessels experienced its storm to hurricane velocities over a region 600 or 700 miles in diameter, with the western gale region closely approaching the central Japanese coast. On the 10th and 11th the typhoon continued into upper latitudes east of the Kuril Islands, and was there lost to observation.

From the standpoint of windiness, the weather at Honolulu was of little interest. The prevailing wind was from the east and the maximum velocity was 23 miles an hour from the same direction on the 23d. The month, however, was one of the warmest in more than 50 years, and was the rainiest September since records began at the station in 1877.

September showed a considerable areal restriction of fog over that of June to August. The summer band of fogginess stretching across the northern waters of the Pacific was now broken into three distinct regions of occurrence—one reaching from northern Japan and the Kuril Islands eastward to about 170° east longitude; another stretching from the eastern Aleutians and the central part of the Gulf of Alaska southward nearly to the fortieth parallel; and the third, along the American coastal region from Vancouver Island to Lower California. In the Asiatic subdivision the heaviest occurrence in a given place had dwindled from 50 per cent in August to 20 per cent of the days in September, and along the California coast it had lessened from about 50 to about 25 per cent. Only along the upper steamer routes between about 45° and 52° N., 145° and 160° W., was there indicated a practically unchanged condition of formation over that of August, with 10 to 25 per cent of days on which fog occurred.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, September, 1930

[For description of tables and charts, see Review, January, 1930, p. 37]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	77.0	+1.6	Wetumpka	101	[1] 1	2 stations	42	[1] 27	6.38	+3.11	Robertsdale	14.23	Demopolis	2.23
Arizona	72.2	−1.4	Parker	115	4	do	23	[1] 13	0.97	−0.10	Bagdad	2.69	11 stations	0.00
Arkansas	75.7	+1.5	Hope	106	8	Dutton	35	27	4.10	+0.67	Harrison	11.80	St. Charles	1.21
California	64.0	−3.3	Greenland Ranch	117	4	Ellery Lake	19	30	0.52	−0.02	Kennett	4.40	20 stations	0.00
Colorado	57.7	+0.1	2 stations	98	[1] 18	3 stations	11	26	1.16	−0.34	Dillon	5.80	Estes Park	0.04
Florida	80.7	+1.3	Bonifay	101	9	Mount Pleasant	59	30	8.70	+1.88	Pensacola	18.65	Key West	2.19
Georgia	77.8	+2.5	Hartwell	101	3	Clayton	45	28	6.01	+2.54	Tallapoosa	13.00	Hartwell	1.98
Idaho	57.9	+1.2	Orofino	100	4	Obsidian	13	23	1.11	+0.09	Roland	2.61	Buhl	0.19
Illinois	69.5	+2.1	2 stations	100	2	Paris	30	28	3.64	+0.02	McLeansboro	10.09	Streator	0.36
Indiana	68.4	+1.4	Rome	100	2	2 stations	30	[1] 29	3.62	+0.50	Mount Vernon	7.72	Whiting	1.29
Iowa	66.3	+2.0	Bonaparte (near)	101	13	Decorah	25	29	2.31	−1.36	Lake Park (near)	6.39	Atlantic	0.17
Kansas	70.8	+1.4	3 stations	102	[1] 1	Tribune	28	27	3.00	+0.12	Coffeyville	11.63	Healy	0.34
Kentucky	72.6	+2.2	do	101	[1] 2	Eubank	38	27	2.46	−0.37	Owensboro	6.87	Willow	0.58
Louisiana	78.1	+0.2	Robeline	102	[1] 12	2 stations	47	28	7.11	+3.15	Port Eads	15.53	Logansport	1.84
Maryland-Delaware	73.0	+5.5	2 stations	102	1	3 stations	33	29	1.47	−1.79	Dover, Del	4.34	Rock Hall, Md	0.26
Michigan	61.3	+1.1	3 stations	95	[1] 12	Roscommon (No. 2)	24	4	2.21	−1.00	Painesdale	6.17	Bay City	0.71
Minnesota	58.4	+0.3	Beardsley	93	18	Big Falls	10	30	3.36	+0.46	New Ulm	10.74	Fergus Falls	0.12
Mississippi	76.9	+1.2	Waynesboro	104	8	2 Stations	44	[1] 27	4.66	+1.58	Pearlington	9.51	West Point	1.56
Missouri	71.3	+2.3	Clinton	105	1	Goodland	37	27	4.18	+0.34	Neosho	12.87	Caruthersville	0.74
Montana	56.4	+1.5	3 stations	93	[1] 3	3 stations	16	[1] 1	1.59	+0.27	Stevensville (near)	4.01	Crow Agency	0.18
Nebraska	65.2	+1.4	do	98	[1] 13	2 stations	29	26	1.61	−0.53	Osmond	5.11	Mary	0.05
Nevada	60.5	−1.0	Logandale	104	17	Zorra Vista Ranch	19	26	0.90	+0.47	Sand Pass	2.65	2 stations	0.00
New England	63.4	+3.2	Fall River, Mass	94	3	Garfield, Vt	22	11	1.65	−1.92	Van Buren, Me	6.42	Hingham, Mass	0.12
New Jersey	69.4	+4.1	Flemington	95	2	Charlotteburg	32	29	2.14	−1.44	Plainfield	4.96	Northfield	0.44
New Mexico	63.8	+0.1	Carlsbad	104	19	Therma	11	27	1.02	−0.49	Solano	5.73	12 stations	0.00
New York	64.0	+2.9	2 stations	93	[1] 2	Gabriels	28	9	2.67	−0.74	Walden	9.77	Bridgehampton	0.34
North Carolina	74.3	+4.0	Weldon	103	3	Banners Elk	32	30	3.79	−0.44	Stonewall	9.10	Weldon	0.64
North Dakota	56.2	−0.2	New Salem	98	4	Carrington	10	28	1.02	−0.62	Park River	3.18	Verona	0.00
Ohio	67.7	+2.1	Portsmouth	99	2	Holgate	30	30	2.72	−0.26	Marion	5.37	Gallipolis	0.71
Oklahoma	77.4	+3.3	Hollis	109	12	2 stations	35	[1] 25	2.24	−1.05	Wyandotte	9.50	Oklahoma City	0.16
Oregon	59.1	+1.0	Umatilla	103	3	Fremont	13	23	1.35	−0.02	Brookings	5.45	Riverside	0.17
Pennsylvania	67.8	+3.8	Arendtsville	101	2	Somerset	27	29	2.45	−1.03	Montrose	7.01	Herrs Island Dam	0.64
South Carolina	77.3	+2.9	2 stations	102	3	4 stations	49	[1] 28	4.58	+0.39	Beaufort (near)	13.60	Clemson College	1.33
South Dakota	61.8	+0.6	3 stations	98	18	2 stations	20	28	1.25	−0.53	Flandreau	5.01	2 stations	T.
Tennessee	74.0	+2.7	Etowah	103	1	Crossville	38	[1] 27	3.30	+0.23	Hohenwald	6.31	Union City	1.09
Texas	79.2	+2.0	Crane (near)	109	12	Romero	35	26	1.90	−0.98	Orange	8.64	8 stations	0.00
Utah	60.2	−0.2	St. George	102	3	2 stations	20	[1] 26	1.86	+0.67	Great Basin Experiment Station, Alpine	5.35	Lemay	0.10
Virginia	74.2	+5.9	5 stations	102	[1] 1	Burkes Garden	32	30	1.35	−1.95	Saltville	3.48	Lincoln	0.28
Washington	59.4	+1.5	Wahluke	100	3	2 stations	20	[1] 24	1.59	−0.46	Quinault	7.25	Cle Elum	T.
West Virginia	69.3	+3.5	Moorefield	106	2	Alpena	29	29	1.46	−1.57	Wheeling	3.81	Lewisburg	0.36
Wisconsin	60.6	+1.1	2 stations	94	[1] 11	2 stations	18	30	3.00	−0.56	Iron River	7.19	Hancock	1.01
Wyoming	54.8	+0.1	Dull Center (near)	94	17	Riverside	13	24	0.92	−0.46	Yoder	3.63	2 stations	0.00
Alaska (August)	53.8	+0.7	Eagle	84	[1] 5	Barrow	26	[1] 19	4.66	+1.19	Mount Roberts (b)	17.44	Tree Point	0.30
Hawaii	76.4	+1.2	Kaanapali	98	15	Volcano Observatory	52	28	9.10	+3.37	Pithonua	42.68	Ka Lae	0.10
Porto Rico	79.1	+0.2	Mayaguez	96	8	Guineo Reservoir	51	25	6.34	−1.70	Maricao	31.15	Ponce	1.22

[1] Other dates also.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

The condition of unusually high atmospheric pressure which prevailed over the Aleutian Islands and the Bering Sea during July and August, continued through the greater part of September. Although the averages of the barometric readings at St. Paul and at Dutch Harbor were no higher than 29.99 and 29.95 inches, respectively, their plus departures from the normal were considerable, as shown in the table. The Aleutian LOW was central at or near Kodiak, where the average pressure for the month was 29.76 inches, but comparatively low barometer prevailed thence south-southwestward into the Tropics. Midway Island, generally in the high-pressure belt in September, now had an average reading of 29.92 inches, which was 0.15 inch below the normal. Thus, nearly north and south in midocean, lay an unusual cyclonic belt, with anticyclonic regions on either side—on the one hand stretching nearly to the American coast; and on the other, to about the one hundred and fifty-fifth meridian of east longitude.

The accompanying table gives the principal barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, September, 1930*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [3]	29.98		30.44	25th	29.40	29th.[6]
Dutch Harbor [2] [3]	29.95	+0.19	30.40	25th	29.18	5th.
St. Paul [2] [3]	29.99	+0.29	30.42	2d	29.58	8th.
Kodiak [3]	29.76	+0.06	30.18	5th	29.26	25th.
Midway Island [2] [3]	29.92	−0.15	30.14	7th	29.53	2d.
Honolulu [4]	29.96	−0.04	30.04	11th	29.85	19th.
Juneau [4]	29.91	−0.01	30.31	6th	29.14	26th.
Tatoosh Island [4] [5]	29.99	−0.02	30.18	19th	29.64	23d.
San Francisco [4] [5]	29.96	+0.02	30.16	25th	29.78	6th.
San Diego [4] [5]	29.93	+0.05	30.09	25th	29.77	27th.

[1] For 26 days.
[2] For 29 days.
[3] P. m. observations only.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.
[6] Also on 30th.

The mid-Pacific trough of low pressure was the scene of considerable storm activity, and here during the early part of the month occurred one of the severest September storms for the region in recent years. The cyclone was probably of tropical origin, with the initial disturbance occurring very close to the one hundred and eightieth meridian. It was first experienced on September 1 some 300 or 400 miles south-southwest of Midway Island, where the American steamer *Steel Scientist* ran into its moderate southerly gales, with barometer even at that time depressed to 29.56 inches. On the 2d, just north of Midway, the storm had perhaps already developed hurricane intensity, since the steamer *President Harrison* steamed at 11 a. m. into a full northeast storm wind, barometer at 29.05, in 29° 14′ N., 177° 50′ W. By the 3d the cyclone was central at about 40° N., 170° W. Late in that day several vessels entered the outer storm region, where they met with strong to whole gales. But it was not until the 4th that the great fury of the cyclone was actually encountered. On this day and on the 5th hurricane velocities were engaged with over an extensive area south of the central and eastern Aleutians. The minimum barometer reading reported was 28.12 inches, read on board the steamer *Iwatesan Maru* in 45° N., 168° W., at 7 a. m. of the 4th. The storm entered the Bering Sea on the 5th and thereafter lost energy, becoming a shallow depression which was lost in the Arctic Ocean on the 7th.

The second progressive mid-ocean cyclone of the month probably developed north of Midway Island on the 15th or 16th, and on the latter date moderate to fresh northerly gales were reported in the vicinity. The storm moved at first with great rapidity toward the northeast, but on the 17th curved into north with lessened speed. During the 18th and 19th it crossed the western part of the Gulf of Alaska, causing fresh to whole gales on the 18th along more than a thousand miles of the upper trans-Pacific steamer route. After entering Alaska, the disturbance turned rapidly eastward into the Canadian Northwest.

From the 24th until the end of September disturbed weather prevailed over the Gulf of Alaska, and fresh to strong gales were experienced on the 26th to 29th in the waters between Sitka and Valdez, and fresh to whole gales on the 25th to 27th over the southern part of the Gulf.

Generally quiet weather prevailed for a long distance west of the coast of the United States, and few extratropical gales were reported as occurring between the western Aleutians and Japan.

The weather was unusually serene for the month in tropical American waters. A brief gale of force 9 from the east-southeast, experienced during a severe thunder squall off the coast between Acapulco and Manzanillo on the 26th, and a moderate south gale in the lower part of the Bay of Panama on the 2d, were the only gale winds reported.

At least one violent typhoon occurred in the Asiatic Tropics. It was first noted east of Guam, traveling westward, on the 3d. On the 7th, after curving through north into northeast, it arrived east of the Ogasawara Islands considerably intensified. It then moved northward again and on the 8th and 9th was central at some distance east of Hondo. On these dates it was unquestionably a violent typhoon, but on the 8th, specifically, reporting vessels experienced its storm to hurricane velocities over a region 600 or 700 miles in diameter, with the western gale region closely approaching the central Japanese coast. On the 10th and 11th the typhoon continued into upper latitudes east of the Kuril Islands, and was there lost to observation.

From the standpoint of windiness, the weather at Honolulu was of little interest. The prevailing wind was from the east and the maximum velocity was 23 miles an hour from the same direction on the 23d. The month, however, was one of the warmest in more than 50 years, and was the rainiest September since records began at the station in 1877.

September showed a considerable areal restriction of fog over that of June to August. The summer band of fogginess stretching across the northern waters of the Pacific was now broken into three distinct regions of occurrence—one reaching from northern Japan and the Kuril Islands eastward to about 170° east longitude; another stretching from the eastern Aleutians and the central part of the Gulf of Alaska southward nearly to the fortieth parallel; and the third, along the American coastal region from Vancouver Island to Lower California. In the Asiatic subdivision the heaviest occurrence in a given place had dwindled from 50 per cent in August to 20 per cent of the days in September, and along the California coast it had lessened from about 50 to about 25 per cent. Only along the upper steamer routes between about 45° and 52° N., 145° and 160° W., was there indicated a practically unchanged condition of formation over that of August, with 10 to 25 per cent of days on which fog occurred.

CLIMATOLOGICAL TABLES

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In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

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The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, September, 1930

[For description of tables and charts, see Review, January, 1930, p. 37]

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	77.0	+1.6	Wetumpka	101	[1] 1	2 stations	42	[1] 27	6.38	+3.11	Robertsdale	14.23	Demopolis	2.23
Arizona	72.2	−1.4	Parker	115	4	do	23	[1] 13	0.97	−0.10	Bagdad	2.69	11 stations	0.00
Arkansas	75.7	+1.5	Hope	106	8	Dutton	35	27	4.10	+0.67	Harrison	11.80	St. Charles	1.21
California	64.0	−3.3	Greenland Ranch	117	4	Ellery Lake	19	30	0.52	−0.02	Kennett	4.40	20 stations	0.00
Colorado	57.7	+0.1	2 stations	98	[1] 18	3 stations	11	26	1.16	−0.34	Dillon	5.80	Estes Park	0.04
Florida	80.7	+1.3	Bonifay	101	9	Mount Pleasant	59	30	8.70	+1.88	Pensacola	18.65	Key West	2.19
Georgia	77.8	+2.5	Hartwell	101	3	Clayton	45	28	6.01	+2.54	Tallapoosa	13.00	Hartwell	1.98
Idaho	57.9	+1.2	Orofino	100	4	Obsidian	13	23	1.11	+0.09	Roland	2.61	Buhl	0.19
Illinois	69.5	+2.1	2 stations	100	2	Paris	30	28	3.64	+0.02	McLeansboro	10.09	Streator	0.36
Indiana	68.4	+1.4	Rome	100	2	2 stations	30	[1] 29	3.62	+0.50	Mount Vernon	7.72	Whiting	1.29
Iowa	66.3	+2.0	Bonaparte (near)	101	13	Decorah	25	29	2.31	−1.36	Lake Park (near)	6.39	Atlantic	0.17
Kansas	70.8	+1.4	3 stations	102	[1] 1	Tribune	28	27	3.00	+0.12	Coffeyville	11.63	Healy	0.34
Kentucky	72.6	+2.2	do	101	[1] 2	Eubank	38	27	2.46	−0.37	Owensboro	6.87	Willow	0.58
Louisiana	78.1	+0.2	Robeline	102	[1] 12	2 stations	47	28	7.11	+3.15	Port Eads	15.53	Logansport	1.84
Maryland-Delaware	73.0	+5.5	2 stations	102	1	3 stations	33	29	1.47	−1.79	Dover, Del	4.34	Rock Hall, Md	0.26
Michigan	61.3	+1.1	3 stations	95	[1] 12	Roscommon (No. 2)	24	4	2.21	−1.00	Painesdale	6.17	Bay City	0.71
Minnesota	58.4	+0.3	Beardsley	93	18	Big Falls	10	30	3.36	+0.46	New Ulm	10.74	Fergus Falls	0.12
Mississippi	76.9	+1.2	Waynesboro	104	8	2 Stations	44	[1] 27	4.66	+1.58	Pearlington	9.51	West Point	1.56
Missouri	71.3	+2.3	Clinton	105	1	Goodland	37	27	4.18	+0.34	Neosho	12.87	Caruthersville	0.74
Montana	56.4	+1.5	3 stations	93	[1] 3	3 stations	16	[1] 1	1.59	+0.27	Stevensville (near)	4.01	Crow Agency	0.18
Nebraska	65.2	+1.4	do	98	[1] 13	2 stations	29	26	1.61	−0.53	Osmond	5.11	Mary	0.05
Nevada	60.5	−1.0	Logandale	104	17	Zorra Vista Ranch	19	26	0.90	+0.47	Sand Pass	2.65	2 stations	0.00
New England	63.4	+3.2	Fall River, Mass	94	3	Garfield, Vt	22	11	1.65	−1.92	Van Buren, Me	6.42	Hingham, Mass	0.12
New Jersey	69.4	+4.1	Flemington	95	2	Charlotteburg	32	29	2.14	−1.44	Plainfield	4.96	Northfield	0.44
New Mexico	63.8	+0.1	Carlsbad	104	19	Therma	11	27	1.02	−0.49	Solano	5.73	12 stations	0.00
New York	64.0	+2.9	2 stations	93	[1] 2	Gabriels	28	9	2.67	−0.74	Walden	9.77	Bridgehampton	0.34
North Carolina	74.3	+4.0	Weldon	103	3	Banners Elk	32	30	3.79	−0.44	Stonewall	9.10	Weldon	0.64
North Dakota	56.2	−0.2	New Salem	98	4	Carrington	10	28	1.02	−0.62	Park River	3.18	Verona	0.00
Ohio	67.7	+2.1	Portsmouth	99	2	Holgate	30	30	2.72	−0.26	Marion	5.37	Gallipolis	0.71
Oklahoma	77.4	+3.3	Hollis	109	12	2 stations	35	[1] 25	2.24	−1.05	Wyandotte	9.50	Oklahoma City	0.16
Oregon	59.1	+1.0	Umatilla	103	3	Fremont	13	23	1.35	−0.02	Brookings	5.45	Riverside	0.17
Pennsylvania	67.8	+3.8	Arendtsville	101	2	Somerset	27	29	2.45	−1.03	Montrose	7.01	Herrs Island Dam	0.64
South Carolina	77.3	+2.9	2 stations	102	3	4 stations	49	[1] 28	4.58	+0.39	Beaufort (near)	13.60	Clemson College	1.33
South Dakota	61.8	+0.6	3 stations	98	18	2 stations	20	28	1.25	−0.53	Flandreau	5.01	2 stations	T.
Tennessee	74.0	+2.7	Etowah	103	1	Crossville	38	[1] 27	3.30	+0.23	Hohenwald	6.31	Union City	1.09
Texas	79.2	+2.0	Crane (near)	109	12	Romero	35	26	1.90	−0.98	Orange	8.64	8 stations	0.00
Utah	60.2	−0.2	St. George	102	3	2 stations	20	[1] 26	1.86	+0.67	Great Basin Experiment Station, Alpine.	5.35	Lemay	0.10
Virginia	74.2	+5.9	5 stations	102	[1] 1	Burkes Garden	32	30	1.35	−1.95	Saltville	3.48	Lincoln	0.28
Washington	59.4	+1.5	Wahluke	100	3	2 stations	20	[1] 24	1.59	−0.46	Quinault	7.25	Cle Elum	T.
West Virginia	69.3	+3.5	Moorefield	106	2	Alpena	29	29	1.46	−1.57	Wheeling	3.81	Lewisburg	0.36
Wisconsin	60.6	+1.1	2 stations	94	[1] 11	2 stations	18	30	3.00	−0.56	Iron River	7.19	Hancock	1.01
Wyoming	54.8	+0.1	Dull Center (near)	94	17	Riverside	13	24	0.92	−0.46	Yoder	3.63	2 stations	0.00
Alaska (August)	53.8	+0.7	Eagle	84	[1] 5	Barrow	26	[1] 19	4.66	+1.19	Mount Roberts (b)	17.44	Tree Point	0.30
Hawaii	76.4	+1.2	Kaanapali	98	15	Volcano Observatory.	52	28	9.10	+3.37	Piihonua	42.68	Ka Lae	0.10
Porto Rico	79.1	+0.2	Mayaguez	96	8	Guineo Reservoir	51	25	6.34	−1.70	Maricao	31.15	Ponce	1.22

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1930*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0-10*	*In.*	*In.*
New England							**65.1**	**+4.3**										**76**	**1.06**	**−2.1**										**5.1**		
Eastport	76	67	85	29.86	29.94	−0.09	58.4	+2.6	74	26	66	45	11	51	22	53	50	80	1.21	−1.6	16	4,905	s.	24	w.	18	4	8	18	7.1	0.0	0.0
Greenville, Me	1,070	6	----	28.79	29.95	----	57.0	----	82	1	66	36	20	48	33	----	----	----	2.28	----	13	3,009	nw.	----	----	----	6	13	11	----	0.0	0.0
Portland, Me	103	82	117	29.85	29.97	−.08	64.6	+5.0	88	3	73	47	11	57	24	57	52	71	1.55	−1.6	7	4,676	w.	22	nw.	23	14	9	7	4.2	0.0	0.0
Concord	289	70	79	29.66	29.97	−.09	63.0	+3.7	87	26	75	36	9	51	39	----	----	----	1.00	−2.4	5	2,706	nw.	15	w.	28	15	10	5	4.1	0.0	0.0
Burlington	403	11	48	29.52	29.95	−.11	61.6	+1.3	85	2	71	38	9	52	35	----	----	----	1.85	−1.6	13	5,224	s.	28	s.	5	4	13	13	6.7	0.0	0.0
Northfield	876	12	60	----	29.98	−.08	58.6	+2.5	84	2	71	32	11	46	41	----	----	81	2.22	−0.8	7	3,794	s.	24	se.	14	4	21	5	6.1	0.0	0.0
Boston	125	106	165	29.84	29.98	−.09	69.4	+6.2	91	16	78	49	30	60	27	60	56	68	0.26	−2.9	3	4,584	sw.	20	sw.	16	9	18	3	4.7	0.0	0.0
Nantucket	12	14	90	29.97	29.98	−.10	67.6	+4.8	83	3	74	52	30	61	18	62	60	83	0.15	−2.3	4	7,965	sw.	28	sw.	12	9	17	4	4.7	0.0	0.0
Block Island	26	11	46	29.95	29.98	−.10	68.3	+4.9	83	3	74	51	30	63	19	63	60	81	0.42	−2.2	4	8,330	sw.	30	w.	27	8	15	7	5.3	0.0	0.0
Providence	160	215	251	29.81	29.98	−.09	68.4	+5.2	90	2	78	47	29	59	27	61	56	71	1.23	−2.0	4	5,800	nw.	36	nw.	6	15	11	4	5.8	0.0	0.0
Hartford	159	122	----	29.82	29.99	−.08	67.5	+5.8	87	2	77	43	29	58	29	----	----	----	1.31	−2.2	6	----	sw.	----	----	----	13	9	8	4.5	0.0	0.0
New Haven	106	74	153	29.88	29.99	−.08	68.3	+4.8	86	3	77	47	29	60	26	62	59	77	0.47	−3.1	8	4,497	s.	23	sw.	28	9	15	6	5.2	0.0	0.0
Middle Atlantic States							**72.3**	**+5.2**										**72**	**1.87**	**−1.3**										**5.0**		
Albany	97	107	115	29.88	29.98	−.09	67.0	+3.9	86	26	77	47	30	57	30	59	55	71	1.96	−1.2	9	3,523	s.	22	se.	5	19	8	3	3.2	0.0	0.0
Binghamton	871	10	84	29.09	30.01	−.06	65.2	+3.9	88	15	77	40	9	54	36	----	----	----	5.37	+2.3	11	2,732	ne.	29	n.	14	7	12	11	5.9	0.0	0.0
New York	314	414	454	29.67	30.00	−.08	71.2	+4.4	89	16	78	51	30	64	20	63	59	71	1.37	−2.0	11	7,776	s.	43	nw.	16	7	15	8	5.7	0.0	0.0
Bellefonte	1,050	5	36	28.90	30.00	----	65.8	----	93	15	81	33	30	51	43	58	53	72	1.42	----	9	----	sw.	----	----	----	10	10	10	5.3	0.0	0.0
Harrisburg	374	94	104	29.62	30.02	−.06	71.8	+6.0	93	2	82	50	29	62	28	62	57	67	2.89	−0.2	8	3,180	w.	30	sw	16	10	14	6	4.8	0.0	0.0
Philadelphia	114	123	367	29.89	30.01	−.07	74.1	+6.1	91	15	82	55	30	66	21	64	59	67	2.57	−0.6	9	6,615	sw	39	w.	2	7	14	9	5.3	0.0	0.0
Reading	325	81	98	29.66	30.00	----	71.4	+5.1	91	2	81	49	30	62	31	62	58	69	3.25	0.0	11	2,879	se.	17	w.	16	9	13	8	5.3	0.0	0.0
Scranton	805	111	119	29.16	30.01	−.06	66.4	+3.5	88	16	78	39	30	55	34	59	55	72	2.76	−0.4	13	3,309	sw.	21	w.	6	12	13	5	4.5	0.0	0.0
Atlantic City	52	37	172	29.95	30.00	−.07	72.3	+5.5	92	3	78	54	30	67	23	66	64	79	0.89	−1.8	9	8,149	s.	36	sw.	16	7	18	5	5.1	0.0	0.0
Cape May	17	13	49	----	----	----	72.6	+3.6	88	25	79	50	30	66	21	67	65	80	2.12	−0.9	5	----	s.	----	----	----	12	10	8	----	0.0	0.0
Sandy Hook	22	10	55	29.96	29.98	----	71.2	----	86	16	77	54	30	66	18	64	61	76	3.33	−0.1	8	7,224	sw.	32	w.	16	7	17	6	5.4	0.0	0.0
Trenton	190	159	183	29.80	30.00	----	70.8	+3.9	90	16	80	49	30	61	30	62	58	71	1.55	−1.8	12	5,114	sw.	37	w.	16	11	11	8	5.1	0.0	0.0
Baltimore	123	100	215	29.85	29.98	−.10	76.2	+7.7	95	25	85	53	30	67	24	65	60	63	0.37	−3.0	8	5,439	sw.	30	nw.	16	8	16	6	5.1	0.0	0.0
Washington	112	62	85	29.89	30.00	−.08	76.0	+7.9	98	2	87	52	28	65	29	65	60	65	0.76	−2.5	4	2,523	s.	22	nw.	27	11	15	4	4.6	0.0	0.0
Cape Henry	18	8	54	29.99	30.01	----	76.8	+5.0	97	15	83	62	30	70	24	70	67	78	0.48	−2.4	6	6,602	sw.	42	nw.	3	10	14	6	4.9	0.0	0.0
Lynchburg	681	153	188	29.30	30.03	−.05	74.5	+5.5	96	2	85	51	28	64	30	64	59	67	0.90	−2.4	7	3,415	w.	32	w.	16	15	10	5	4.0	0.0	0.0
Norfolk	91	170	205	29.93	30.02	−.04	77.7	+6.1	96	3	86	61	30	70	24	69	66	76	0.57	−2.7	5	6,796	s.	29	sw.	16	10	12	8	5.4	0.0	0.0
Richmond	144	11	52	29.87	30.02	−.05	76.8	+6.3	97	2	87	55	28	66	27	66	63	72	1.37	−1.9	7	3,779	sw.	23	sw.	16	11	13	6	4.6	0.0	0.0
Wytheville	2,304	49	55	27.71	30.03	−.04	68.0	+4.4	90	1	78	44	30	58	34	61	58	79	1.09	−2.2	9	2,854	w.	22	nw.	14	7	13	10	6.0	0.0	0.0
South Atlantic States							**77.5**	**+4.2**										**83**	**4.52**	**+0.3**										**6.0**		
Asheville	2,253	70	84	27.75	30.05	−.02	69.0	+4.0	88	1	78	45	28	60	29	62	60	84	4.23	+1.2	16	3,200	se.	19	n.	8	4	14	12	6.5	0.0	0.0
Charlotte	779	55	62	29.22	30.04	−.03	76.2	+4.7	97	3	85	55	30	67	28	68	65	78	2.90	−0.1	11	2,234	sw.	14	sw.	15	8	11	11	5.7	0.0	0.0
Greensboro	886	5	56	29.10	30.05	----	74.4	----	98	3	85	43	30	64	38	66	64	82	1.79	----	10	4,202	sw.	28	nw.	7	7	10	13	6.1	0.0	0.0
Hatteras	11	5	50	30.00	30.01	−.05	78.4	+3.9	87	26	84	66	19	73	17	74	72	84	4.78	+0.2	10	7,189	sw.	60	n.	12	11	10	9	5.0	0.0	0.0
Raleigh	376	103	110	29.64	30.02	−.05	76.6	+5.5	97	3	86	58	28	68	26	69	66	78	3.31	−0.3	8	4,087	sw.	34	n.	7	7	14	9	6.0	0.0	0.0
Wilmington	78	81	91	29.97	30.05	.00	78.6	+5.5	91	14	86	63	29	71	22	72	71	86	5.82	+1.3	12	3,420	sw.	19	w.	17	6	14	10	6.0	0.0	0.0
Charleston	48	11	92	29.99	30.04	.00	80.2	+3.6	92	14	86	66	30	74	17	75	73	84	3.22	−1.3	14	5,336	sw.	24	sw.	16	6	13	11	5.9	0.0	0.0
Columbia, S. C	351	41	57	29.67	30.04	−.01	78.0	+3.5	96	3	87	58	30	69	26	70	68	82	3.78	+0.3	14	3,247	s.	25	sw.	15	4	18	8	5.7	0.0	0.0
Due West	711	10	55	29.30	30.07	----	76.0	----	96	3	85	56	30	67	29	----	----	----	2.15	----	11	4,142	sw.	25	w.	16	4	13	13	6.4	0.0	0.0
Greenville, S. C	1,039	139	146	28.96	30.04	----	75.3	+4.7	95	3	84	58	28	67	28	67	64	79	2.74	−0.9	12	4,221	ne.	22	w.	14	4	16	10	6.1	0.0	0.0
Augusta	182	62	77	29.83	30.02	−.03	79.1	+3.8	96	14	88	58	30	70	25	71	69	82	5.85	+2.5	10	2,578	s.	19	sw.	26	6	15	9	5.8	0.0	0.0
Savannah	65	150	194	29.96	30.02	−.01	80.0	+3.8	94	14	88	64	30	72	22	74	72	87	9.43	+4.0	18	5,549	s.	31	w.	26	4	15	11	6.2	0.0	0.0
Jacksonville	43	209	245	29.97	30.02	+.02	81.0	+2.7	93	12	88	67	30	74	20	74	73	86	3.62	−3.7	15	5,875	e.	38	s.	14	4	15	11	6.3	0.0	0.0
Florida Peninsula							**82.3**	**+1.6**										**80**	**3.79**	**−3.4**										**5.9**		
Key West	22	10	64	29.94	29.96	+0.02	83.4	+1.2	90	12	88	73	2	79	15	77	75	78	2.19	−4.5	12	6,258	se.	25	s.	6	7	15	8	5.8	0.0	0.0
Miami	25	124	168	29.97	30.00	+.02	82.2	+2.1	88	15	87	74	9	78	13	77	74	78	5.05	−3.3	20	6,400	se.	27	s.	8	7	13	10	5.9	0.0	0.0
Tampa	35	79	197	29.96	29.99	+.02	81.4	+1.5	94	24	89	70	8	74	20	74	73	84	4.13	−2.3	19	6,121	e.	37	e.	18	3	19	8	6.4	0.0	0.0
Titusville	44	5	----	29.96	30.01	----	82.3	----	96	26	90	71	15	74	23	----	----	----	6.84	----	15	----	se.	----	----	----	9	13	8	5.4	0.0	0.0
East Gulf States							**77.4**	**+1.7**										**82**	**6.74**	**+2.5**										**6.3**		
Atlanta	1,173	190	216	28.82	30.03	−.02	75.6	+3.2	92	1	83	56	28	68	26	67	65	77	3.52	+0.5	14	3,857	e.	23	se.	4	5	9	16	6.8	0.0	0.0
Macon	370	78	87	29.64	30.03	.00	77.8	+3.0	94	4	87	56	28	68	29	70	68	80	2.30	−0.9	10	2,809	s.	16	s.	16	4	14	12	6.7	0.0	0.0
Thomasville	273	49	103	29.72	30.01	.00	79.1	+2.3	93	8	88	65	30	70	22	72	70	86	8.09	+3.2	15	3,506	se.	26	w.	13	3	15	12	6.8	0.0	0.0
Apalachicola	36	11	51	29.96	30.00	----	80.0	----	89	12	86	68	30	74	18	75	73	82	10.18	+2.1	17	4,902	se.	31	se.	2	13	10	7	5.0	0.0	0.0
Pensacola	56	149	185	29.94	30.00	+.01	77.5	−0.5	89	9	83	62	29	72	16	74	72	84	18.65	+13.3	14	6,648	ne.	36	nw.	20	3	12	15	6.8	0.0	0.0
Anniston	741	9	57	29.26	30.04	+.01	75.6	+4.3	96	9	86	49	28	65	31	----	----	----	4.19	+0.5	13	1,927	s.	14	nw.	10	9	12	9	5.3	0.0	0.0
Birmingham	700	11	48	29.27	30.02	−.01	76.6	+1.8	96	9	86	52	28	67	29	69	67	82	3.08	−0.3	10	3,077	s.	18	se.	4	6	13	11	6.0	0.0	0.0
Mobile	57	125	161	29.93	29.99	−.01	78.4	+0.3	94	1	85	64	29	72	22	73	71	86	11.49	+6.5	13	4,850	n.	30	se.	4	2	11	17	7.1	0.0	0.0
Montgomery	223	100	112	29.77	30.02	.00	78.2	+1.9	96	9	87	60	28	70	25	70	68	79	6.78	+3.8	14	2,786	ne.	24	n.	9	6	11	13	6.6	0.0	0.0
Corinth	469	6	----	----	----	----	76.5	----	100	7	88	47	27	65	39	----	----	----	8.36	----	9	----	se.	----	----	----	8	20	2	----	0.0	0.0
Meridian	375	87	95	29.61	30.00	−.02	76.4	+1.9	95	8	85	52	28	68	26	70	68	82	2.35	−0.6	12	2,790	ne.	19	sw.	15	5	12	13	6.5	0.0	0.0
Vicksburg	247	65	73	29.73	30.00	−.02	77.2	+0.9	96	8	86	55	28	68	24	69	67	80	2.93	+0.1	10	3,707	se.	21	s.	15	9	12	9	5.4	0.0	0.0
New Orleans	53	76	84	29.92	29.97	−.01	79.2	0.0	92	4	86	64	15	73	22	73	72	85	7.30	+2.3	20	3,428	ne.	18	sw.	15	3	17	10	6.4	0.0	0.0
West Gulf States							**78.8**	**+1.7**										**73**	**3.96**	**−0.6**										**4.5**		
Shreveport	249	77	93	29.69	29.96	−.04	78.3	+1.4	98	12	88	55	27	68	25	70	67	76	4.88	+2.1	11	3,207	se.	29	ne	3	11	13	6	4.7	0.0	0.0
Bentonville	1,303	11	44	28.62	29.96	−.06	72.8	+3.9	97	1	84	44	27	61	32	----	----	----	5.73	----	7	2,998	s.	20	ne.	15	25	2	3	----	0.0	0.0
Fort Smith	457	79	94	29.48	29.95	−.06	77.4	+3.4	100	7	89	48	27	66	33	67	62	65	2.47	−0.5	8	4,360	e.	46	nw.	14	12	12	6	4.3	0.0	0.0
Little Rock	357	136	153	29.60	29.97	−.06	76.5	+2.4	97	13	86	51	27	67	30	67	63	70	2.86	−0.3	9	4,434	s.	39	nw.	15	9	12	9	5.2	0.0	0.0
Austin	605	136	148	29.31	29.94	----	79.7	+1.4	98	1	90	58	18	69	32	69	64	68	3.01	−0.4	7	4,469	se.	33	n.	10	9	16	5	4.7	0.0	0.0
Brownsville	57	83	100	29.84	29.90	----	82.6	+2.0	94	11	91	65	16	75	25	74	72	81	2.80	−2.7	8	6,555	se.	38	n.	16	13	13	4	4.4	0.0	0.0
Corpus Christi	20	11	78	29.90	29.92	−.03	81.6	+1.9	96	15	88	67	17	75	26	75	73	80	3.72	−0.8	10	7,746	se.	38	ne.	3	10	14	6	5.0	0.0	0.0
Dallas	512	220	227	29.41	29.94	----	78.4	----	98	12	88	55	26	69	29	----	----	----	1.65	−1.1	6	6,413	se.	50	w.	14	23	4	3	2.8	0.0	0.0
Fort Worth	670	106	114	29.23	29.94	−.05	78.9	+2.0	100	12	89	53	27	68	28	68	63	65	1.19	−1.3	4	5,481	se.	27	sw.	25	15	9	6	4.0	0.0	0.0
Galveston	54	106	114	29.91	29.97	−.01	79.8	−0.3	90	2	84	65	27	75	16	74	72	79	4.41	−1.2	9	6,853	s.	25	s.	15	6	16	8	5.4	0.0	0.0
Groesbeck	461	11	56	29.47	29.94	----	78.4	----	96	8	88	54	27	68	27	----	----	----	3.11	+0.1	6	5,857	s.	27	sw.	26	13	11	6	4.2	0.0	0.0
Houston	138	292	314	29.81	29.96	----	79.2	+0.2	97	11	88	60	27	71	24	----	----	----	2.14	−1.9	8	7,356	ne.	37	n.	26	7	17	6	4.9	0.0	0.0
Palestine	510	64	72	29.44	29.96	−.03	77.6	+0.6	95	12	87	53	27	68	24	69	65	74	2.46	−0.4	10	4,198	s.	22	nw.	15	14	11	5	3.9	0.0	0.0
Port Arthur	34	58	66	29.91	29.95	----	78.8	----	94	11	86	60	27	72	23	73	71	82	5.39	+0.6	12	4,814	e.	35	nw.	18	4	15	11	5.9	0.0	0.0
San Antonio	693	242	301	29.21	29.91	−.05	80.7	+1.7	100	11	92	58	27	70	28	69	64	64	1.74	−1.3	5	7,050	se.	36	e.	3	11	15	4	4.1	0.0	0.0
Taylor	571	38	51	29.38	29.98	+.01	79.0	+2.1	98	8	90	54	27	68	30	----	----	----	4.08	+0.7	6	4,681	s.	23	s.	14	15	14	1	3.6	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							71.5	+2.8										71	2.82	−0.2										5.4		
Chattanooga	762	190	215	29.22	30.01	−0.05	75.2	+3.0	95	1	84	53	30	67	27	67	64	75	3.32	+0.2	15	3,442	se.	29	nw.	13	4	17	9	6.1	0.0	0.0
Knoxville	995	102	111	29.00	30.03	−.03	73.9	+3.3	95	1	83	49	30	65	28	66	63	77	4.56	+1.9	12	2,972	ne.	25	n.	14	5	15	10	6.1	0.0	0.0
Memphis	399	76	97	29.56	29.98	−.05	76.8	+3.2	97	2	86	53	27	68	26	67	63	70	2.12	−0.7	9	4,148	s.	36	n.	12	6	13	11	6.0	0.0	0.0
Nashville	546	168	191	29.45	30.03	−.03	74.4	+2.6	96	2	84	47	27	65	33	66	61	72	3.88	+0.5	7	4,076	s.	38	nw.	7	9	13	8	5.4	0.0	0.0
Lexington	989	193	230	29.00	30.05	−.02	71.2	+2.7	94	2	80	46	27	62	33				2.80	−0.3	7	6,961	sw.	50	nw.	14	11	8	11	5.4	0.0	0.0
Louisville	525	188	234	29.45	30.03	−.03	71.9	+1.4	94	2	81	50	27	63	29	63	59	71	2.35	−0.4	9	5,188	s.	49	w.	2	9	13	8	5.3	0.0	0.0
Evansville	431	76	116	29.54	30.00	−.06	72.8	+2.1	95	2	82	51	27	64	28	64	60	73	3.39	+0.1	11	4,565	s.	38	nw.	2	10	7	13	5.7	0.0	0.0
Indianapolis	822	194	230	29.12	30.00	−.06	69.2	+2.3	88	2	79	43	30	60	27	60	55	67	2.86	−0.5	8	5,871	sw.	44	nw.	14	12	11	7	4.9	0.0	0.0
Royal Center	736	11	55	29.21	30.00		65.4		87	13	77	33	30	54	35				4.52	+1.6	9	4,985	s.	28	sw.	26	11	11	8	4.8	0.0	0.0
Terre Haute	575	96	129	29.38	29.99		70.3		90	2	80	45	30	60	32	61	57	70	3.95	+0.3	8	5,018	s.	33	nw.	14	11	6	13	5.2	0.0	0.0
Cincinnati	627	11	51	29.35	30.02	−.05	70.2	+3.1	92	2	81	44	30	60	33	61	56	70	4.38	+1.7	11	3,551	sw.	27	sw.	2	10	7	13	5.2	0.0	0.0
Columbus	822	216	230	29.15	30.01	−.06	69.0	+2.5	89	23	78	43	30	59	31	60	54	67	1.05	−1.5	7	5,752	sw.	37	w.	26	12	10	8	4.7	0.0	0.0
Dayton	899	137	173	29.06	30.00		69.0	+2.4	88	2	79	43	30	59	29	60	56	71	2.76	−0.2	8	4,441	sw.	33	sw.	26	14	9	7	4.2	0.0	0.0
Elkins	1,947	59	67	28.03	30.04	−.04	66.2	+3.2	90	1	79	35	29	53	37	58	55	76	1.44	−1.7	8	2,308	w.	20	w.	27	5	13	12	6.4	0.0	0.0
Parkersburg	637	77	82	29.39	30.04	−.04	70.8	+3.5	95	2	82	43	29	59	33	60	55	67	1.01	−1.8	10	2,885	se.	24	nw.	26	9	11	10	5.9	0.0	0.0
Pittsburgh	842	353	410	29.12	30.01	−.07	69.8	+3.4	92	2	80	44	30	60	32	59	53	64	0.74	−1.8	9	5,239	sw.	28	sw.	3	11	12	7	5.1	0.0	0.0
Lower Lake Region							65.5	+2.6										70	2.56	−0.4										4.8		
Buffalo	767	247	280	29.14	29.96	−.10	64.9	+2.5	83	26	71	42	30	58	23	60	57	78	1.56	−1.4	8	9,896	sw.	62	sw.	27	12	11	7	4.4	0.0	0.0
Canton	448	10	61	29.47	29.94		61.0	+1.7	86	2	71	34	9	51	32				1.51	−1.8	13	4,988	sw.	30	sw.	15	4	17	9	5.6	0.0	0.0
Ithaca	836	5	100	29.09	29.99		64.2	+2.6	87	12	76	37	30	53	38	56	53	76	2.07	−1.0	8	4,505	s.	25	s.	5	8	17	5	5.0	0.0	0.0
Oswego	335	76	91	29.60	29.97	−.09	64.0	+2.8	86	15	72	45	29	56	33	58	54	72	3.91	+1.2	10	4,846	s.	22	w.	27	6	17	7	5.6	0.0	0.0
Rochester	523	86	102	29.42	29.99	−.07	65.4	+3.0	88	15	74	42	30	56	32	56	51	66	1.55	−0.9	6	4,253	sw.	28	sw.	26	9	13	8	5.5	0.0	0.0
Syracuse	596	65	79	29.34	29.98	−.09	66.5	+4.9	90	12	76	44	9	57	34				3.20	+0.5	11	3,612	s.	18	nw.	3	11	10	9	5.1	0.0	0.0
Erie	714	130	166	29.22	29.98	−.08	66.6	+3.0	87	2	74	45	29	59	28	59	54	69	2.64	−0.8	9	7,653	sw.	39	sw.	26	14	8	8	4.1	0.0	0.0
Cleveland	762	267	337	29.18	30.00	−.06	67.2	+3.3	87	1	74	45	29	61	30	58	52	63	1.69	−1.6	9	8,109	s.	40	s.	26	12	7	11	5.2	0.0	0.0
Sandusky	629	5	67	29.33	30.01	−.05	67.6	+2.3	89	13	77	42	29	58	34				3.88	+0.9	8	4,904	sw.	26	sw.	26	11	12	7	4.6	0.0	0.0
Toledo	628	208	243	29.33	30.00	−.06	66.3	+1.9	88	13	75	42	30	57	28	58	52	66	2.24	−0.6	8	8,010	sw.	46	sw.	26	16	8	6	3.9	0.0	0.0
Fort Wayne	856	100	119	29.08	30.00		66.3	+0.8	88	13	76	40	28	56	30	58	54	72	3.45	+0.4	12	5,071	sw.	31	sw.	26	9	11	10	5.4	0.0	0.0
Detroit	730	218	268	29.22	30.00	−.06	66.2	+2.7	87	13	75	42	29	57	30	57	52	69	2.97	+0.1	9	5,983	sw.	48	sw.	26	17	8	5	3.5	0.0	0.0
Upper Lake Region							61.1	+1.5										71	2.33	−1.0										4.8		
Alpena	609	13	92	29.28	29.95	−.08	58.7	+1.1	85	19	69	36	29	49	30	53	49	77	1.47	−1.5	10	6,585	nw.	30	s.	26	7	15	8	5.4	0.0	0.0
Escanaba	612	54	60	29.26	29.92	−.09	57.7	+0.6	79	1	66	35	30	49	27	52	47	73	1.74	−1.6	9	6,108	s.	25	sw.	26	13	12	5	4.4	0.0	0.0
Grand Haven	632	54	89	29.27	29.94	−.10	62.8	+1.9	82	23	71	38	30	55	25	57	52	69	1.28	−2.4	8	7,420	sw.	42	sw.	26	11	12	7	4.9	0.0	0.0
Grand Rapids	707	70	244	29.22	29.98	−.07	65.2	+2.5	89	12	76	39	30	55	33	55	49	63	1.48	−2.0	8	7,464	sw.	54	sw.	26	9	11	10	5.2	0.0	0.0
Houghton	668	64	99	29.16	29.88	−.12	56.6	−0.3	84	23	65	34	30	48	33				4.23	+0.7	18	7,146	w.	36	w.	26	5	13	12	6.1	0.0	0.0
Lansing	878	6	49	29.04	29.98		63.0	+1.6	88	13	75	36	29	51	34	56	52	75	1.42	−1.5	10	2,966	w.	19	w.	27	17	6	7	4.0	0.0	0.0
Ludington	637	60	66	29.25	29.95		61.2	+1.9	80	23	68	43	28	54	26	55	51	70	2.21	−1.0	7	7,378	s.	49	sw.	26	15	12	3	3.5	0.0	0.0
Marquette	734	77	111	29.10	29.90	−.10	58.8	+1.3	83	24	68	39	30	50	30	51	47	71	3.63	+0.4	15	6,951	w.	31	sw.	19	6	9	15	6.6	0.0	0.0
Port Huron	638	70	120	29.29	29.98	−.08	64.0	+2.4	86	14	74	38	29	54	29	56	51	71	2.12	−0.7	6	6,653	w.	31	sw.	26	11	12	7	4.7	0.0	0.0
Sault Sainte Marie	614	11	52	29.23	29.92	−.10	56.8	+1.3	83	1	65	38	22	49	29	52	49	79	3.42	−0.8	13	5,690	nw.	29	nw.	17	11	9	10	5.2	0.0	0.0
Chicago	673	7	131	29.26	29.98	−.06	66.9	+1.7	89	13	75	40	28	59	30	58	53	68	1.29	−1.8	6	6,048	sw.	36	sw.	26	16	7	7	4.1	0.0	0.0
Green Bay	617	109	141	29.26	29.92	−.10	62.4	+2.0	88	23	73	35	28	52	35	53	47	65	1.64	−1.9	8	7,012	s.	34	w.	26	11	8	11	5.2	0.0	0.0
Milwaukee	681	125	221	29.22	29.95	−.08	65.0	+2.5	87	12	73	40	28	57	29	57	51	67	1.97	−1.3	7	7,778	w.	44	sw.	26	18	5	7	3.7	0.0	0.0
Duluth	1,133	5	47	28.70	29.92	−.06	55.8	+0.7	83	11	66	30	30	46	32	49	45	78	4.68	+1.4	12	8,149	w.	36	nw.	4	13	11	6	4.2	0.0	0.0
North Dakota							57.1	−0.1										62	1.62	−0.6										4.1		
Moorhead	940	50	58	28.90	29.92	−.04	58.8	+0.6	89	23	71	24	28	46	41	49	41	58	0.52	−1.7	3	5,491	nw.	27	sw.	23	10	15	5	4.6	0.0	0.0
Bismarck	1,674	8	57	28.14	29.92	−.02	57.7	−0.4	88	10	70	25	28	45	38	48	41	63	2.70	+1.5	7	5,710	nw.	38	w.	11	15	10	5	3.7	0.0	0.0
Devils Lake	1,478	11	44	28.34	29.91	−.03	55.5	−0.4	90	10	68	17	28	42	39	46	39	63	0.96	−0.7	5	5,834	w.	31	sw.	24	11	11	8	4.6	0.0	0.0
Ellendale	1,457	10	56	28.38	29.95		57.0		85	23	70	22	28	44	43				0.29	−1.7	4	8,016	nw.	37	sw.	23	15	8	7	4.3	0.0	0.0
Grand Forks	833	12	67				56.4		87	23	69	21	29	44	40	49			1.43		6		nw.	36	sw.	23	10	19	1		0.0	0.0
Williston	1,878	41	48	27.94	29.91	−.02	56.4	−0.2	86	10	69	26	27	44	43	47	41	64	0.65	−0.4	7	4,783	w.	32	w.	24	19	8	3	3.2	0.2	0.0
Upper Mississippi Valley							67.4	+2.2										67	2.71	−0.9										4.3		
Minneapolis	918	102	208	28.94	29.91		62.4	+1.0	88	12	73	34	28	52	35				4.14	+1.0	9	7,221	w.	42	n.	26	13	7	10	4.6	0.0	0.0
St. Paul	837	236	261	29.02	29.92	−.07	61.5	+0.2	86	12	72	34	28	51	38				2.90	−0.2	9	7,786	se.	47	nw.	26	13	10	7	4.3	0.0	0.0
La Crosse	714	11	48	29.16	29.93	−.08	62.1	−0.1	90	23	74	33	28	50	45	54	50	72	3.51	−0.5	9	2,478	s.	17	nw.	26	18	5	7	3.9	0.0	0.0
Madison	974	70	78	29.02	29.95	−.08	63.8	+1.4	87	12	73	36	28	54	32	55	49	66	4.79	+1.1	10	4,973	s.	23	s.	26	20	3	7	3.7	0.0	0.0
Wausau	1,247	4	62	28.61	29.94		60.8		87	23	73	30	30	49	42				2.10	−1.6	9	4,054	w.	23	nw.	26	11	9	10	5.4	0.0	0.0
Charles City	1,015	10	51	28.89	29.96	−.04	62.4	+1.4	89	18	75	32	28	50	41	53	48	68	2.48	−1.2	9	3,835	se.	24	nw.	26	20	6	4	2.8	0.0	0.0
Davenport	606	71	79	29.30	29.95	−.08	68.9	+3.3	93	13	80	41	28	58	32	58	53	64	0.39	−3.2	4	5,604	s.	39	sw.	26	16	7	7	4.1	0.0	0.0
Des Moines	861	5	99	29.04	29.93	−.09	68.2	+2.6	94	22	81	39	28	56	41	57	51	62	1.53	−2.1	5	5,705	s.	38	nw.	26	12	9	9	4.8	0.0	0.0
Dubuque	700	81	96	29.21	29.95	−.08	65.6	+1.6	89	12	77	38	30	55	40	56	50	67	2.53	−1.5	5	3,790	s.	19	s.	26	19	5	6	3.5	0.0	0.0
Keokuk	614	64	78	29.30	29.97	−.06	71.0	+3.5	97	1	82	45	28	60	33	60	54	63	2.97	−0.9	4	4,341	sw.	38	w.	14	15	7	8	4.3	0.0	0.0
Cairo	358	87	93	29.61	29.98	−.07	74.0	+2.5	94	2	83	50	27	65	28	65	62	74	2.65	−0.2	8	4,096	s.	30	sw.	24	8	7	15	6.2	0.0	0.0
Peoria	609	11	45	29.33	29.99	−.05	69.8	+5.5	94	13	82	38	28	58	37	59	54	68	1.31	−2.7	6	3,464	s.	27	sw.	14	19	8	3	2.9	0.0	0.0
Springfield, Ill	636	154	191	29.31	29.98	−.07	69.9	+2.3	92	1	80	45	28	60	27	60	55	67	2.71	−0.9	8	7,203	s.	46	sw.	25	15	5	10	4.5	0.0	0.0
Hannibal	534	74	109	29.41	29.97	−.06	71.4	+3.7	98	1	82	43	28	61	33				3.12	−0.8	4	5,024	sw.	36	sw.	26	13	8	9	4.7	0.0	0.0
St. Louis	568	265	303	29.37	29.97	−.07	72.6	+2.5	96	1	82	50	27	64	29	62	57	67	3.51	0.0	8	7,044	sw.	54	nw.	14	16	4	10	4.4	0.0	0.0
Missouri Valley							67.9	+1.8										64	2.48	−0.7										3.9		
Columbia, Mo	784	6	84	29.14	29.96	−.07	70.6	+2.4	100	1	81	46	27	60	35				3.39	−1.0	9	4,260	s.	31	sw.	25	13	8	9	4.6	0.0	0.0
Kansas City	963	161	181	28.92	29.94	−.08	72.4	+3.5	97	1	82	47	26	63	39	63	57	66	2.61	−2.0	11	5,396	s.	36	nw.	13	13	10	7	4.2	0.0	0.0
St. Joseph	967	11	49	28.91	29.93		70.2		93	13	81	44	26	60	39	61	57	71	2.75	−1.1	10	4,444	se.	33	w.	25	16	8	6	3.7	0.0	0.0
Springfield, Mo	1,324	98	104	28.61	29.99	−.04	71.4	+2.5	95	1	80	46	26	63	27	63	58	70	3.25	−0.3	7	6,144	s.	31	s.	25	21	7	2	2.2	0.0	0.0
Iola	984	11	50	28.90	29.92	−.09	72.4	+2.6	100	1	84	44	28	61	39				6.72	+1.8	9	3,167	s.	26	nw.	14	15	5	10	4.4	0.0	0.0
Topeka	987	92	107				71.6	+2.9	97	1	82	47	26	61	43				5.85	+2.0	10	5,385	sw.	35	w.	25	13	10	7	4.3	0.0	0.0
Lincoln	1,189	11	81	28.68	29.92	−.07	68.0	+1.6	95	22	80	43	26	56	39	59	54	67	1.36	−1.6	5	5,554	s.	34	nw.	26	13	10	7	4.3	0.0	0.0
Omaha	1,105	115	122	28.77	29.93	−.07	68.6	+1.8	93	22	79	43	26	58	35	58	52	63	0.65	−2.6	4	4,147	s.	32	nw.	26	17	6	7	3.7	0.0	0.0
Valentine	2,598	47	54	27.26	29.95	−.01	63.6	+1.1	94	18	78	34	25	49	44	52	44	60	0.54	−0.8	5	5,034	w.	36	sw.	22	12	16	2	3.7	T.	0.0
Sioux City	1,135	94	164	28.75	29.94	−.04	65.8	+2.4	90	12	77	41	27	54	40	56	50	64	2.46	−0.6	6	7,098	se.	39	nw.	26	13	11	6	4.5	0.0	0.0
Huron	1,306	59	74	28.57	29.96	−.00	61.2	−0.1	89	4	74	29	27	48	38	52	45	62	1.34	−0.2	6	5,483	w.	26	w.	18	18	8	4	3.3	0.0	0.0
Pierre	1,572	70	75	28.27	29.92	−.03	64.0	+0.2	93	18	77	35	29	51	40	52	43	54	0.25	−0.8	2	5,520	e.	30	w.	18	14	13	3	4.2	0.0	0.0
Yankton	1,233	49	57	28.64	29.95	−.03	65.2	+1.2	90	18	77	39	27	54	40				1.04	−1.7	6	4,441	nw.	25	sw.	23	15	10	8	3.8	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, September, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope							**58.3**	**+1.0**										**59**	**1.13**	**−0.1**										**4.4**		
Billings	3,140	5					59.1		89	4	77	27	26	41	53				0.68		6		nw.				9	9	12		0.0	0.0
Havre	2,505	11	44	27.31	29.92	−0.02	57.6	+1.2	89	3	71	33	20	44	44	48	40	61	1.39	+0.1	10	3,722	sw.	27	sw.	10	10	13	7	5.0	T.	0.0
Helena	4,124	89	113	25.78	29.92	−.05	57.7	+1.1	86	3	69	32	24	46	39	47	38	55	1.12	−0.1	8	5,127	sw.	27	sw.	23	7	14	9	5.7	0.0	0.0
Kalispell	2,973	48	56	26.90	29.92	−.04	56.9	+3.4	85	4	69	33	1	45	38	48	42	63	2.67	+1.4	7	3,144	nw.	24	ne.	21	7	7	16	6.2	0.0	0.0
Miles City	2,371	48	55	27.43	29.95	.00	60.8	−0.4	88	17	74	32	26	47	44	50	43	58	1.06	0.0	5	3,716	s.	24	w.	23	11	17	2	4.1	0.0	0.0
Rapid City	3,259	50	58	26.60	29.98	+.02	60.9	+.05	94	22	75	33	25	47	39	49	39	54	0.76	−0.4	3	4,122	w.	25	sw.	22	13	12	5	4.6	T.	0.0
Cheyenne	6,088	84	101	24.06	29.95	−.01	56.8	−0.2	80	20	70	32	26	43	43	45	38	57	1.28	+0.1	8	5,997	w.	36	nw.	25	14	10	6	4.2	0.0	0.0
Lander	5,372	60	68	24.66	29.94	−.02	57.4	+1.7	85	18	73	28	26	42	50	46	39	57	0.10	−0.8	2	2,966	sw.	25	sw.	10	20	8	2	2.9	0.0	0.0
Sheridan	3,790	10	47	26.07	29.94		57.2		87	3	75	27	26	39	51	46	37	58	T.	−1.3	0	2,273	nw.	19	nw.	23	19	8	3	3.2	0.0	0.0
Yellowstone Park	6,241	11	48		29.98	+.01	51.2	−2.2	77	3	64	26	1	38	39			62	1.36	+0.1	10	4,328	sw.	30	sw.	11	7	16	7		1.3	0.0
North Platte	2,821	11	51	27.05	29.94	−.03	65.6	+3.5	95	18	80	37	25	52	42	55	49	66	1.52	+0.2	5	3,544	se.	25	sw.	13	16	10	4	3.9	0.0	0.0
Middle slope							**70.2**	**+2.1**										**59**	**2.11**	**−0.2**										**3.9**		
Denver	5,292	106	113	24.76	29.94	−.02	63.8	+0.9	86	18	76	36	26	51	37	49	38	46	0.27	−0.7	4	4,220	s.	28	w.	25	14	10	6	4.7	0.0	0.0
Pueblo	4,685	80	86	25.27	29.88	−.08	65.6	+1.0	92	18	80	32	26	51	41	51	41	50	1.03	+0.3	4	3,941	e.	34	nw.	25	15	12	3	4.1	0.0	0.0
Concordia	1,392	50	58	28.50	29.95	−.04	70.2	+1.9	93	22	82	43	26	58	45	60	55	68	1.78	−0.8	4	4,416	s.	30	nw.	25	18	8	4	3.7	0.0	0.0
Dodge City	2,509	11	51	27.38	29.94	−.04	71.3	+1.9	94	22	84	40	26	58	40	59	52	63	2.70	+0.8	6	5,501	se.	28	nw.	25	22	6	2	2.2	0.0	0.0
Wichita	1,358	139	158	28.51	29.91	−.09	72.9	+2.3	94	12	84	44	26	62	45	63	57	65	5.29	+2.2	10	7,591	s.	42	sw.	25	13	14	3	4.0	0.0	0.0
Broken Arrow	765	11	56	29.14	29.96		75.8		101	12	87	47	26	64	34				3.52	−0.1	7	7,785	s.	66	nw.	25	12	9	9	4.6	0.0	0.0
Oklahoma City	1,214	10	47	28.67	29.92	−.07	77.6	+4.8	102	12	90	45	26	66	40	64	58	60	0.16	−2.9	3	5,799	s.	28	nw.	25	16	7	7	4.3	0.0	0.0
Southern slope							**77.5**	**+4.0**										**49**	**1.41**	**−1.1**										**3.4**		
Abilene	1,738	10	52	28.15	29.91	−.05	79.4	+4.1	100	12	91	52	27	68	30	64	56	55	4.85	+2.2	5	5,967	s.	28	w.	8	15	9	6	3.8	0.0	0.0
Amarillo	3,676	10	49	26.27	29.92	−.04	73.8	+4.5	98	19	88	40	26	60	36	57	46	48	0.20	−2.1	4	6,005	s.	24	s.	22	14	15	1	3.6	0.0	0.0
Del Rio	944	64	71	28.90	29.86	−.08	83.4	+4.2	102	11	94	65	27	73	29	68	60	52	0.04	−2.9	1	5,499	se.	26	n.	26	20	8	2	3.0	0.0	0.0
Roswell	3,566	75	85	26.35	29.89	−.03	73.3	+3.0	100	19	88	47	28	58	43	56	43	42	0.55	−1.6	4	4,380	s.	24	sw.	22	16	11	3	3.4	0.0	0.0
Southern plateau							**70.7**	**−0.1**										**42**	**0.49**	**−0.3**										**2.8**		
El Paso	3,778	152	175	26.17	29.85	−.03	77.3	+3.4	97	18	90	55	28	65	33	56	38	29	0.04	−1.2	2	6,105	e.	36	w.	22	22	8	0	2.4	0.0	0.0
Santa Fe	7,013	38	53	23.33	29.90	−.03	60.4	−0.5	81	1	73	34	26	48	34	46	35	46	1.89	+0.4	6	3,495	se.	26	sw.	22	15	7	8	4.2	0.0	0.0
Flagstaff	6,907	10	59	23.41	29.89	.00	55.8	+0.3	81	4	71	30	25	41	43	45		62	2.06		3	5,105	sw.	26	sw.	30	9	16	5		0.0	0.0
Phoenix	1,108	10	107	28.66	29.79	−.02	82.2	−0.5	108	4	97	59	25	68	39	61	46	34	0.51	−0.2	2	3,263	e.	28	sw.	6	20	5	5	2.7	0.0	0.0
Yuma	141	9	54	29.65	29.79	+.01	82.2	−1.5	110	3	98	56	27	67	42	63	51	41	T.	−0.4	0	3,064	w.	18	ne.	22	23	7	0	1.7	0.0	0.0
Independence	3,957	6	27	25.91	29.89	+.03	66.4	−1.6	94	4	83	33	30	50	40	48			T.	−0.1	0		s.				21	21	5		0.0	0.0
Middle Plateau							**61.7**	**−0.2**										**42**	**1.12**	**+0.4**										**3.7**		
Reno	4,532	74	81	25.43	29.88	−.07	60.4	+0.7	88	2	75	32	25	46	39	46	34	46	1.15	+0.9	4	4,196	w.	30	w.	22	17	8	5	3.4	0.0	0.0
Tonopah	6,090	12	20				62.0		83	3	72	32	30	52	29	45	29	31	0.02		1		se.									
Winnemucca	4,344	18	56	25.58	29.92	−.01	58.7	−0.5	89	2	76	29	25	41	48	45	33	47	1.06	+0.6	8	3,524	sw.	26	nw.	4	18	7	5	3.4	0.0	0.0
Modena	5,473	10	43	24.61	29.87	−.05	59.4	−0.6	86	3	76	26	26	43	43	45	30	39	0.27	−0.5	4	6,769	sw.	36	s.	10	11	16	3	3.7	0.0	0.0
Salt Lake City	4,360	163	203	25.60	29.91	−.04	64.4	0.0	87	18	75	39	26	54	31	50	39	44	2.40	+1.4	10	4,734	s.	47	sw.	4	15	7	8	3.8	0.0	0.0
Grand Junction	4,602	60	68	25.38	29.93	−.02	65.6	−0.6	91	2	78	37	26	53	34	50	37	42	0.70	−0.2	8	3,812	se.	23	w.	22	13	9	8	4.3	0.0	0.0
Northern Plateau							**62.4**	**+1.8**										**50**	**0.97**	**+0.2**										**4.8**		
Baker	3,471	48	53	26.42	29.98	−.01	57.2	+1.2	90	3	71	30	23	43	44	47	37	52	0.73	0.0	9	3,113	se.	17	sw.	17	11	8	11	5.1	0.0	0.0
Boise	2,739	78	86	27.11	29.93	−.04	63.2	+1.3	90	21	77	37	23	50	39	50	40	49	0.96	+0.4	7	2,373	nw.	14	nw.	10	16	4	10	4.4	0.0	0.0
Lewiston	757	40	48	29.12	29.92	−.06	65.4	+2.6	97	3	79	39	24	52	44				0.88	−0.1	6	1,586	e.	20	nw.	6	10	8	12	5.4	0.0	0.0
Pocatello	4,477	60	68	25.46	29.92	−.04	61.6	+1.4	86	20	75	38	27	48	43	48	37	48	1.17	+0.4	7	5,194	se.	30	sw.	11	15	13	2	3.9	0.0	0.0
Spokane	1,929	101	110	27.90	29.93	−.05	61.9	+2.7	90	4	74	34	24	50	42	51	41	54	0.75	−0.2	7	3,043	s.	21	s.	6	10	11	9	5.1	0.0	0.0
Walla Walla	991	57	65	28.87	29.93	−.07	65.4	+1.6	96	3	77	46	24	54	38	53	41	46	1.33	+0.4	6	2,262	s.	16	sw.	6	12	6	12	5.1	0.0	0.0
North Pacific Coast Region							**59.6**	**+1.0**										**73**	**1.59**	**−0.3**										**5.7**		
North Head	211	11	56	29.79	30.01	−.02	56.2	−0.3	76	2	60	47	30	52	26	54	53	93	2.97	0.0	12	7,899	n.	46	s.	25	2	8	20	7.9	0.0	0.0
Port Angeles	29	8	53		30.02		54.8		76	2	62	37	23	47	30				0.83	−0.6	8	3,043	s.	19	w.	6	11	10	9		0.0	0.0
Seattle	125	215	250	29.85	29.98	−.03	59.4	+1.3	84	2	66	42	30	53	26	55	51	75	1.14	−0.6	10	4,119	s.	23	s.	13	9	7	14	6.2	0.0	0.0
Tacoma	194	172	201	29.80	30.00	−.02	59.3	+2.0	81	2	66	38	30	52	26				0.87	−1.2	6	4,619	n.	28	sw.	6	9	7	14	6.2	0.0	0.0
Tatoosh Island	86	9	35	29.90	29.99	−.02	53.8	+0.8	66	8	58	45	29	50	15	53	52	94	3.81	−0.9	14	7,211	s.	37	e.	23	9	3	18	6.7	0.0	0.0
Yakima	1,076	58	67	28.79	29.93		63.7	+2.6	92	3	77	37	25	51	38	52	42	51	0.15	−0.4	2	3,042	nw.	17	w.	6	14	11	5	3.7	0.0	0.0
Medford	1,329	29	58	28.55	29.94		63.0		97	2	78	35	23	48	46	53	44	62	1.58	+1.1	11		nw.	25	n.	6	16	6	8	4.1	0.0	0.0
Portland, Oreg	153	68	106	29.82	29.98	−.05	63.7	+2.0	97	2	72	44	23	55	36	56	51	68	1.79	−0.2	10	3,183	nw.	18	nw.	16	9	6	15	6.0	0.0	0.0
Roseburg	510	75	99	29.44	29.98	−.04	61.2	−1.7	92	2	73	37	23	49	41	54	49	69	1.18	−0.1	9	2,081	n.	16	sw.	9	9	11	10	5.0	0.0	0.0
Middle Pacific Coast Region							**63.5**	**−1.2**										**72**	**0.43**	**−0.2**										**4.7**		
Eureka	62	73	89	29.94	30.02	+.01	56.8	+0.9	68	27	61	49	25	53	15	54	53	89	1.12	+0.1	6	3,017	nw.	23	n.	29	2	8	20	7.9	0.0	0.0
Red Bluff	330	5	58	29.54	29.89	−.04	69.2	−3.9	95	2	82	51	23	56	41	57	48	53	0.58	−0.2	8	3,188	s.	18	se.	7	17	5	8	3.8	0.0	0.0
Sacramento	69	106	117	29.84	29.91	+.02	65.6	−3.7	91	2	78	48	29	53	37	57	51	65	0.29	−0.1	4	5,056	s.	19	sw.	7	22	5	3	2.3	0.0	0.0
San Francisco	155	208	243	29.79	29.96	+.02	62.4	+1.5	75	26	68	54	6	57	17	58	55	80	0.10	−0.4	3	4,767	w.	24	w.	22	8	15	7	5.3	0.0	0.0
San Jose	141	12	110	29.83	29.98		63.7	−1.0	82	1	74	44	25	53	35				0.05	−0.3	3	3,793	nw.	21	sw.	7	15	12	3	4.1	0.0	0.0
South Pacific Coast Region							**68.1**	**−1.7**										**68**	**0.67**	**−0.1**										**3.8**		
Fresno	327	89	98	29.56	29.91	+.04	69.6	−3.8	96	3	84	49	25	56	38	57	48	52	0.20	0.0	2	4,280	nw.	21	nw.	28	21	5	4	2.7	0.0	0.0
Los Angeles	338	159	191	29.58	29.94	+.06	67.9	−1.1	93	4	76	55	30	60	25	60	56	73	0.01	−0.2	1	2,828	sw.	12	sw.	21	13	14	3	4.0	0.0	0.0
San Diego	87	62	70	29.84	29.93	+.04	66.9	−0.2	79	4	72	56	30	62	15	62	59	78	T.	−0.1	0	3,868	w.	17	nw.	3	9	17	4	4.8	0.0	0.0
West Indies																																
San Juan, P. R	82	9	54	29.88	29.96		80.6	+0.1	87	4	85	74	19	76	13				5.70	−0.2	16	7,461	e.	42	e.	2	2	22	6	5.9	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97		[1] 29.80	−.02	80.8	+1.0	92	10	87	70	2	74	17			[1] 86	7.61	−0.3	19	4,247	nw.	24	nw.	14	0	10	20	8.1	0.0	0.0
Cristobal	36	6	97		[1] 29.81	−.02	81.8	+1.4	89	19	87	73	2	77	15	77	76	[1] 84	10.88	−1.5	21	5,260	w.	22	w.	14	1	9	20	8.0	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[2] 29.31	[2] 29.83		42.2		68	9	50	22	21	35	30	40	36	77	1.29		14	2,650	sw.				5	5	20	7.7	3.2	T.
Juneau	80	11	50	[2] 29.82	[2] 29.91		50.2		68	6	55	34	22	45	23	48	46	84	9.75		26	4,986	w.	32	e.	26	5	2	23	7.9	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 29.92	[2] 29.96		79.3	+1.1	86	17	84	72	20	75	12	73	70	77	7.74	+6.5	15	5,238	e.	23	e.	13	8	17	5	5.2	0.0	0.0

[1] Observations taken bihourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, September, 1930*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				54.3		62.2	46.4	70	35	3.00		0.0
Sydney, C. B. I.	48												
Halifax, N. S.	88												
Yarmouth, N. S.	65												
Charlottetown, P. E. I.	38												
Chatham, N. B.	28												
Father Point, Que.	20												
Quebec, Que.	296	29.60	29.92	−0.09	56.0	+0.9	62.6	49.4	79	40	4.18	+0.51	0.0
Doucet, Que.	1,236												
Montreal, Que.	187	29.71	29.91	−.13	60.7	+2.3	67.5	54.0	84	46	2.39	−0.91	0.0
Ottawa, Ont.	236	29.67	29.93	−.11	60.8	+3.4	70.8	50.8	90	38	2.58	−0.11	0.0
Kingston, Ont.	285	29.65	29.96	−.08	63.1	+3.1	69.6	56.6	78	45	1.07	−1.73	0.0
Toronto, Ont.	379	29.56	29.96	−.10	63.1	+4.1	72.5	53.6	87	39	2.83	−0.42	0.0
Cochrane, Ont.	930				51.0		59.4	42.6	81	28	2.86		0.0
White River, Ont.	1,244	28.53	29.84	−.14	49.7	−0.6	60.4	39.1	76	25	5.02	+2.25	0.0
London, Ont.	808				63.1		75.4	50.8	90	36	2.16		0.0
Southampton, Ont.	656	29.24	29.95	−.10	60.6	+3.1	69.9	51.4	84	37	1.52	−1.42	0.0
Parry Sound, Ont.	688	29.24	29.92	−.11	59.7	+3.7	68.2	51.2	81	40	2.48	−1.19	0.0
Port Arthur, Ont.	644	29.18	29.89	−.09	53.2	+1.0	62.0	44.4	78	31	4.21	+0.73	0.0
Winnipeg, Man.	760	29.05	29.88	−.06	54.8	+2.3	65.2	44.5	85	26	1.30	−0.73	0.0
Minnedosa, Man.	1,690	28.08	29.89	−.05	50.9	+0.4	64.2	37.6	83	13	0.22	−1.14	0.0
Le Pas, Man.	860				48.3		56.9	39.7	72	22	2.19		0.0
Qu'Appelle, Sask.	2,115	27.64	29.87	−.05	51.6	+0.5	63.3	39.9	82	21	0.92	−0.41	0.0
Moose Jaw, Sask.	1,759				54.5		68.2	40.8	88	24	1.37		0.0
Swift Current, Sask.	2,392	27.34	29.84	−.08	54.2	+1.1	68.5	39.9	87	26	2.67	+1.45	0.0
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.34	29.91	+.01	50.4	+2.0	59.5	41.4	83	23	3.82	+2.54	0.0
Battleford, Sask.	1,592	28.15	29.88	−.02	52.5	+0.7	64.6	40.5	88	23	2.16	+0.91	0.0
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.72	29.97	−.04	57.5	+2.7	64.0	51.0	82	46	1.04	−1.12	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												
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Sydney, C. B. I.	48	29.97	30.02	+0.07	65.5	+2.2	74.5	56.5	83	48	3.24	−0.38	0.0
Yarmouth, N. S.	65	29.89	29.96	−.01	62.4	+2.2	71.3	53.5	79	44	2.01	−1.61	0.0
Father Point, Que.	20	29.91	29.93	+.02	56.1	+0.5	62.9	49.3	73	42	5.48	+2.43	0.0
Winnepeg, Man.	760	29.18	30.00	+.06	69.4	+6.0	82.1	56.8	92	44	0.97	−1.70	0.0
Medicine Hat, Alb.	2,144	27.54	29.74	−.18	68.4	+2.7	82.7	54.0	97	41	1.15	−0.52	0.0
Banff, Alb.	4,521	25.48	29.99	+.08	57.9	+1.6	74.3	41.4	87	31	2.13	−0.40	1.5
Kamloops, B. C.	1,262	28.70	29.96	+.05	69.7	+1.1	83.3	56.1	94	47	0.57	−0.52	0.0
Estevan Point, B. C.	20				58.1		65.4	50.9	70	46	0.68		0.0
Prince Rupert, B. C.	170				61.1		70.1	52.2	80	48	0.82		0.0

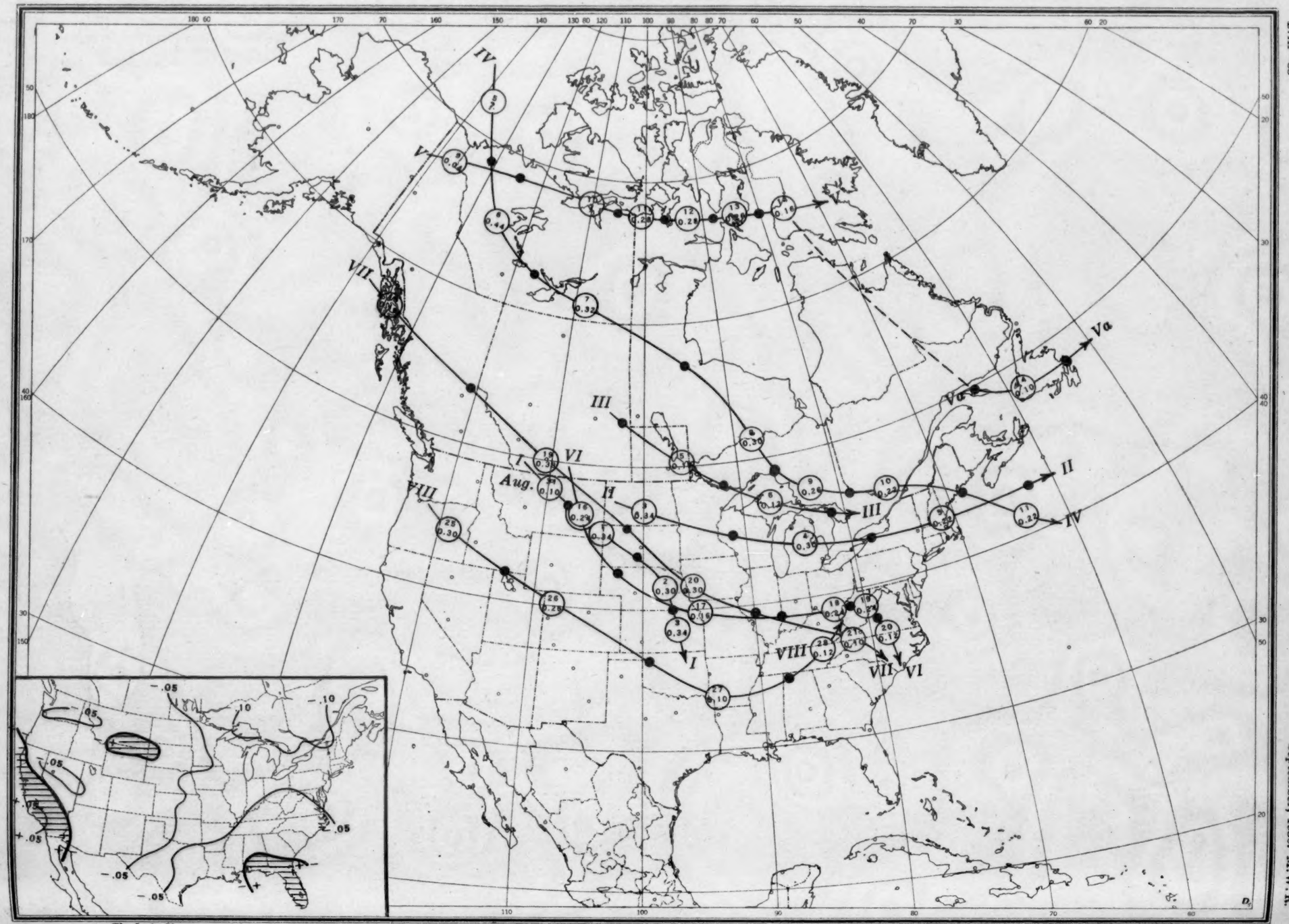
Chart I. Departure (°F.) of the Mean Temperature from the Normal, September, 1930

Chart I. Departure (°F.) of the Mean Temperature from the Normal, September, 1930

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, September, 1930. (Inset) **Departure of Monthly Mean Pressure from Normal**

(Plotted by Welby R. Stevens)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

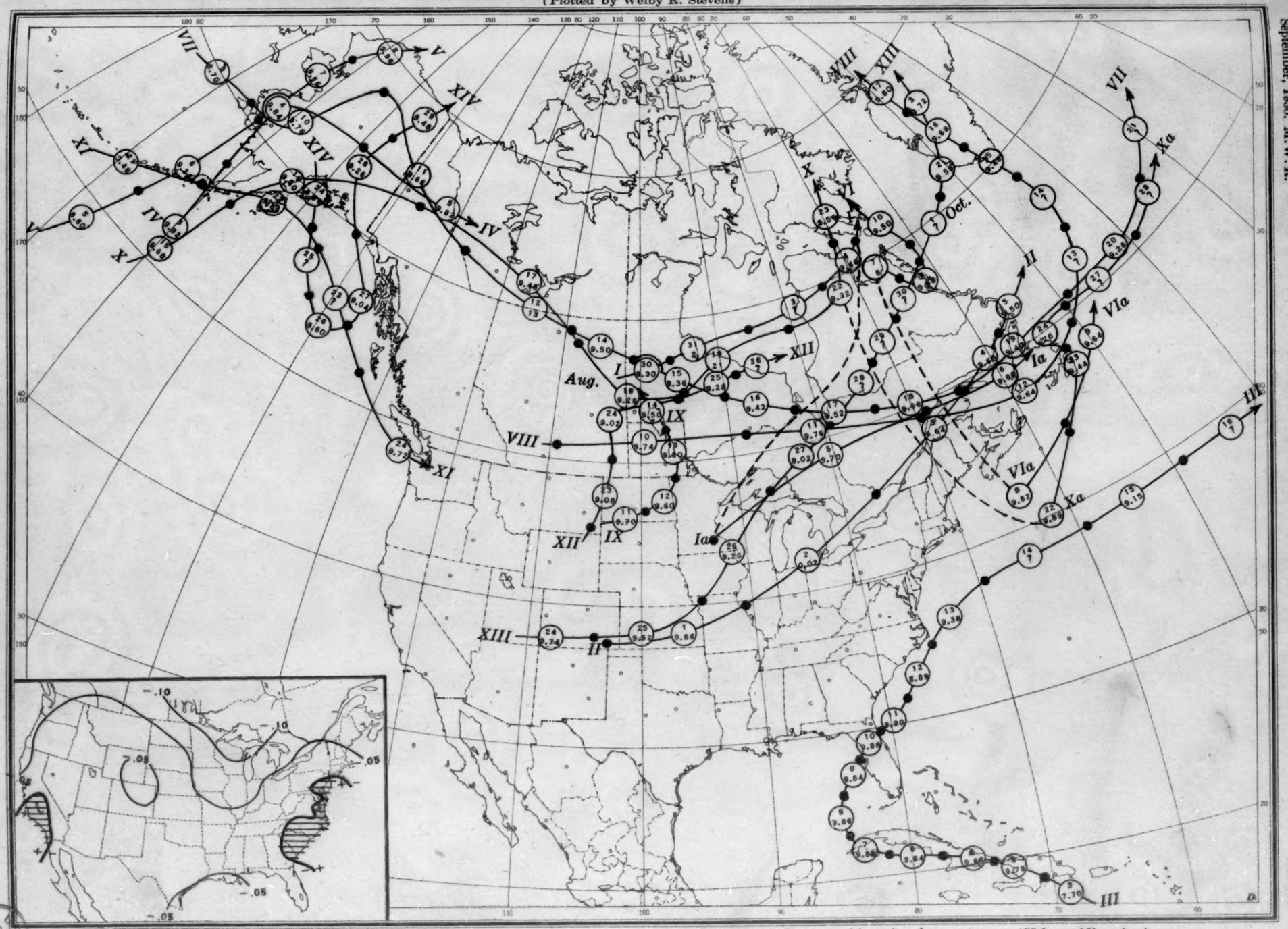
Chart III. Tracks of Centers of Cyclones, September, 1930. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by Welby R. Stevens)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, September, 1930. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by Welby R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, September, 1930

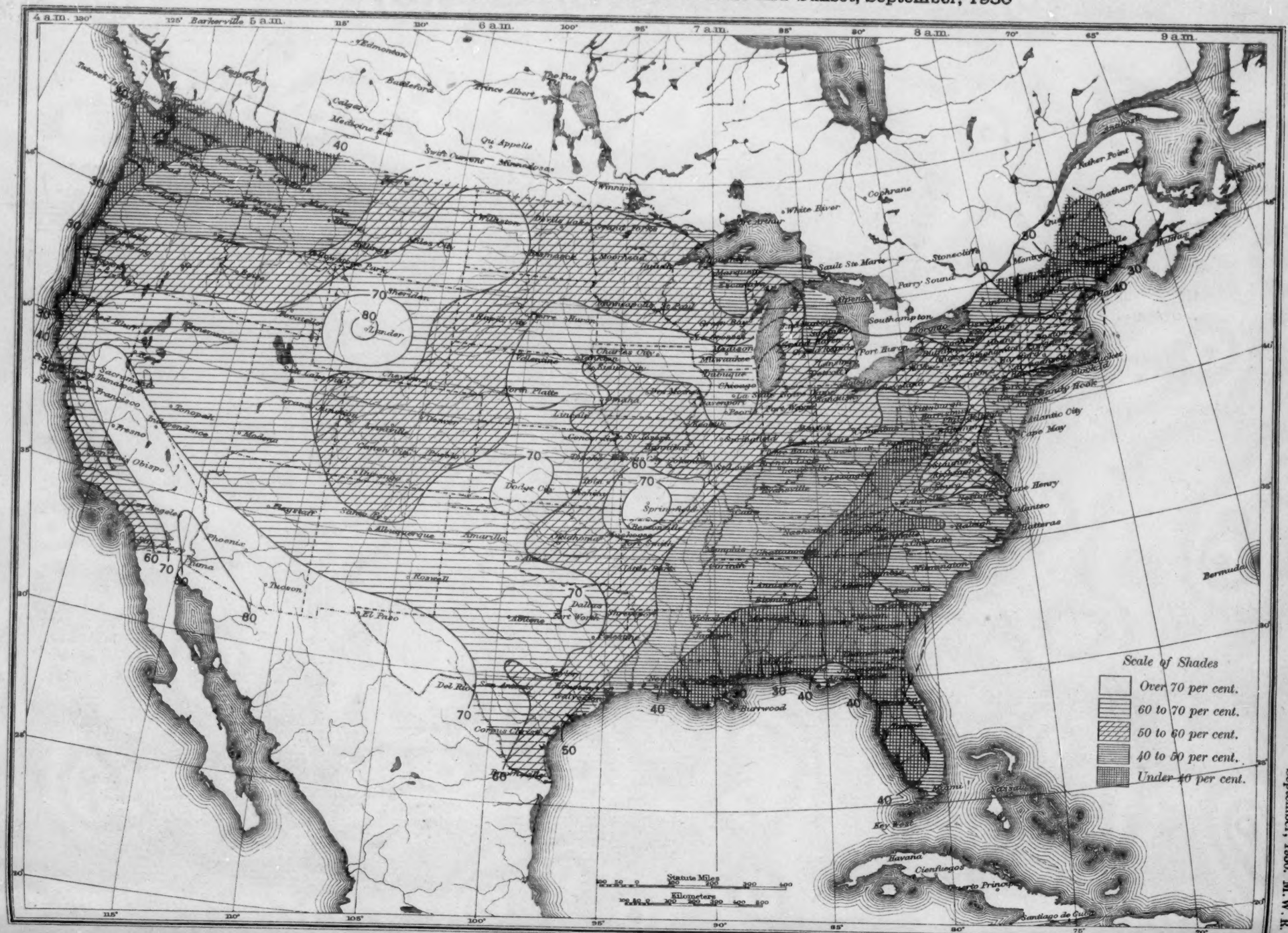


Chart V. Total Precipitation, Inches, September, 1930. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, September, 1930. (Inset) Departure of Precipitation from Normal

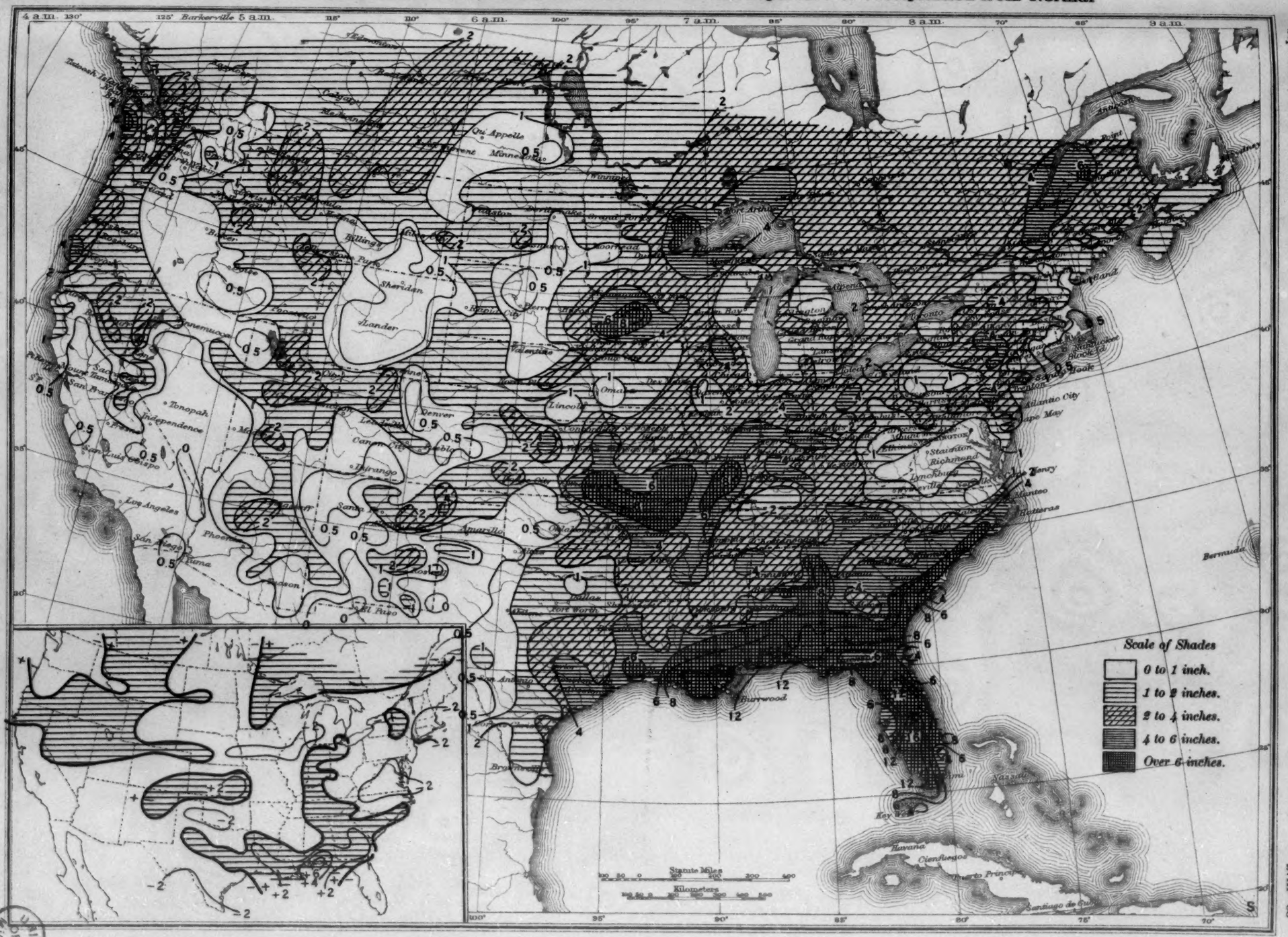


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, September, 1930

Chart VIII. Weather Map of North Atlantic Ocean, September 1, 1930

(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, September 1, 1930

(Plotted by F. A. Young)

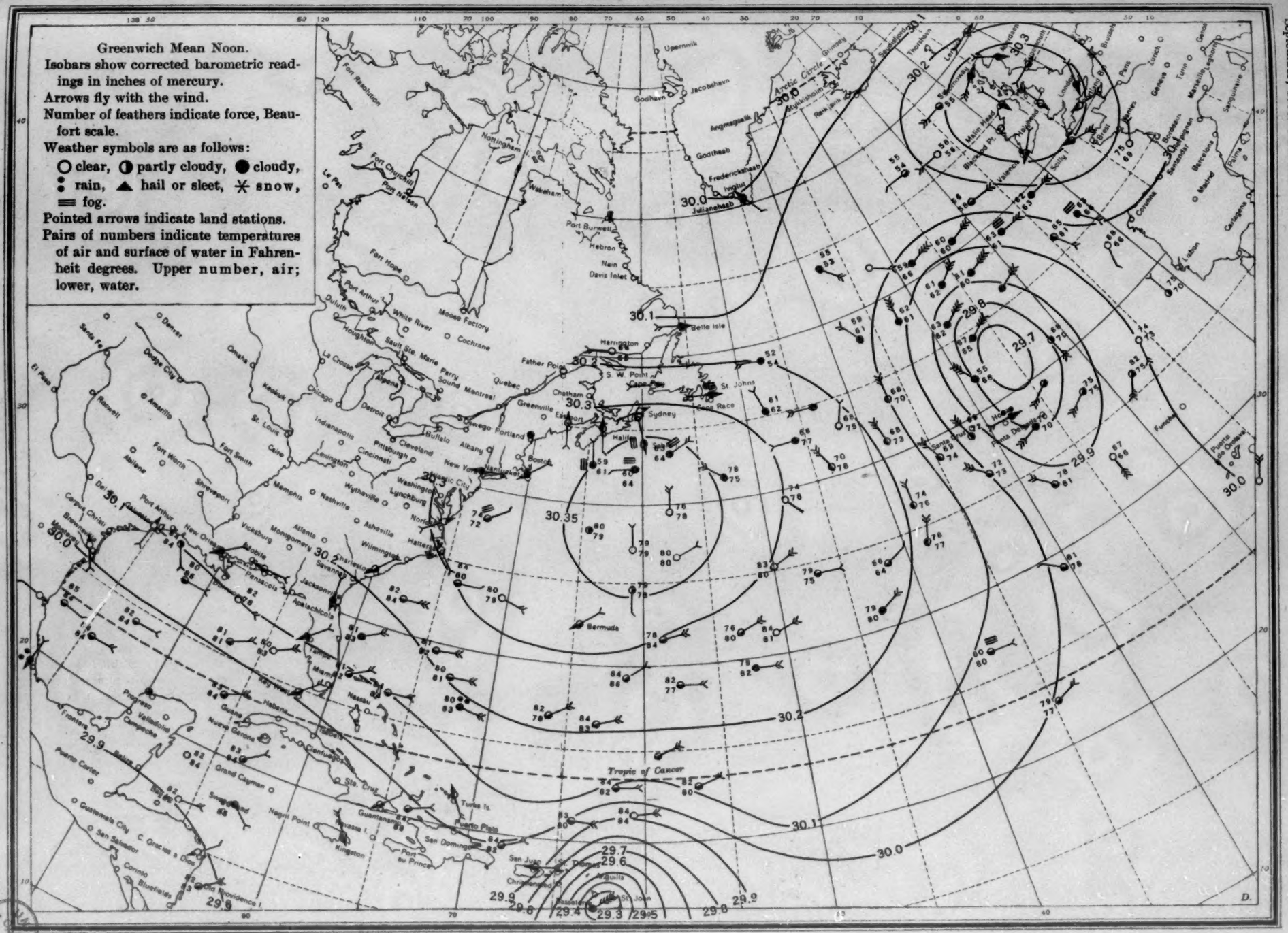


Chart IX. Weather Map of North Atlantic Ocean, September 2, 1930

(Plotted by F. A. Young)

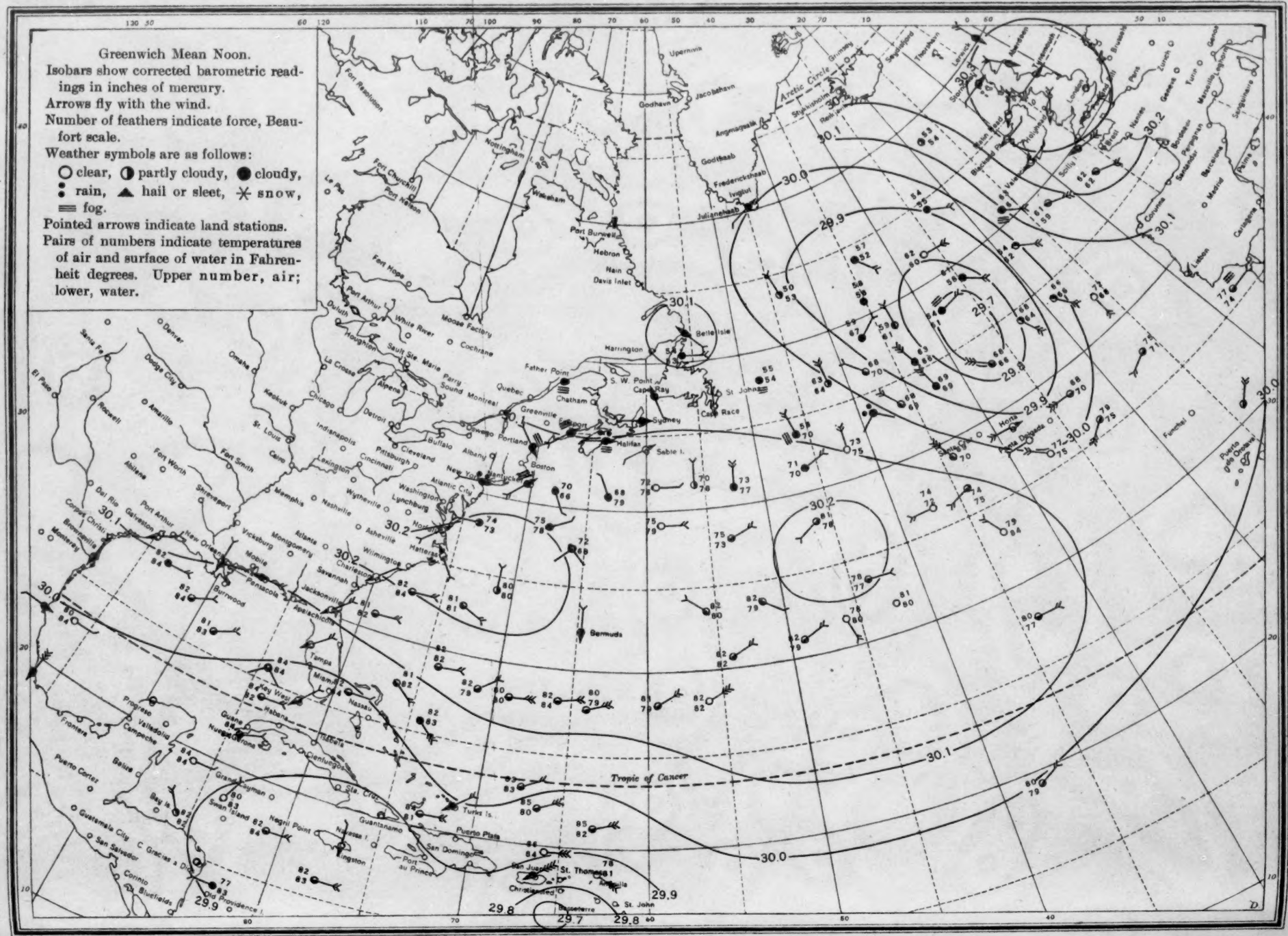

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer
Bermuda
Halifax
Sydney
Boston
New York
Washington
Atlantic City
Cape Race
St. Johns
Belle Isle
Godthaab
Julianehaab
Fredericksdal
Ivigtut
Godhavn
Jacobshavn
Upernivik
Angmagssalik
Port Burwell
Hebron
Nain
Davis Inlet
Fort Chimo
Fort Nelson
Fort Churchill
Fort Hope
Port Arthur
Duluth
White River
Moose Factory
Cochrane
Sault Ste. Marie
Parry Sound
Montreal
Quebec
Father Point
Chatham
Greenville
Portland
Harrington
S. W. Point
Cape Ray
Sable I.
Chicago
Detroit
Cleveland
Buffalo
Albany
Pittsburgh
Cincinnati
Indianapolis
Keokuk
La Crosse
Alpena
St. Louis
Omaha
Denver
Santa Fe
El Paso
Roswell
Dodge City
Amarillo
Abilene
Fort Worth
Fort Smith
Shreveport
Cairo
Memphis
Nashville
Lexington
Wytheville
Lynchburg
Norfolk
Asheville
Hatteras
Wilmington
Charleston
Savannah
Jacksonville
Apalachicola
Tampa
Miami
Key West
Nassau
Havana
Matanzas
Cienfuegos
Sta. Cruz
Guantanamo
Turks Is.
Puerto Plata
San Domingo
Port au Prince
Jamaica
Negril Point
Grand Cayman
Swan Island
Bay Is.
Belize
Puerto Cortez
Guatemala City
San Salvador
Corinto
Bluefields
Old Providence I.
Progreso
Campeche
Frontera
Vera Cruz
Tuxpan
Tampico
Port Isabel
Brownsville
Corpus Christi
Galveston
Port Arthur
New Orleans
Vicksburg
Mobile
Pensacola
Burwood
Montgomery
Atlanta
Monterey
Del Rio
Mazatlan
Manzanillo
Acapulco
Salina Cruz
Puerto Barrios
Progreso
Valladolid
Campeche
Frontera
Belize
Puerto Cortez
Guatemala City
San Salvador
Corinto
Bluefields
Old Providence I.
Grand Cayman
Swan Island
Bay Is.
Negril Point
Nassau
Havana
Matanzas
Cienfuegos
Sta. Cruz
Guantanamo
Turks Is.
Puerto Plata
San Domingo
Port au Prince
Jamaica
St. Thomas
San Juan
Christiansted
Basseterre
St. John
Martinique
Barbados
Trinidad
Curacao
Puerto Cabello
Maracaibo
Coro
Caracas
Cumana
Carupano
Guiria
Port of Spain
Grenada
St. Vincent
Kingston
Tobago
Funchal
Horta
Ponta Delgada
Puerto de la Orotava
Lisbon
Madrid
Coruna
Cartagena
Barcelona
Palma
Marseilles
Genoa
Leghorn
Naples
Bordeaux
Pauillac
Santander
Corunna
Gibraltar
Malaga
Oran
Algiers
Tunis
Bizerta
Malta
Zurich
Geneva
Turin
Paris
Brussels
Amsterdam
Rotterdam
Ymuiden
Aberdeen
Lerwick
Stornoway
Thorshavn
Skudesnaes
Skagastrand
Grimsey
Akureyri
Isafjord
Reykjavik
Stykkisholm
Blacksod Point
Valentia
Scilly I.
Holyhead
Fastnet
Queenstown
Belfast
Donaghadee
Prestwick
Greenock
Liverpool
Manchester
Holyhead
Falmouth
Portland Bill
Dungeness
Yarmouth
Harwich
Lowestoft
Aberdeen
Kinnaird Head
Wick
Thurso
Lerwick
Stornoway

Chart X. Weather Map of North Atlantic Ocean, September 3, 1930

(Plotted by F. A. Young)

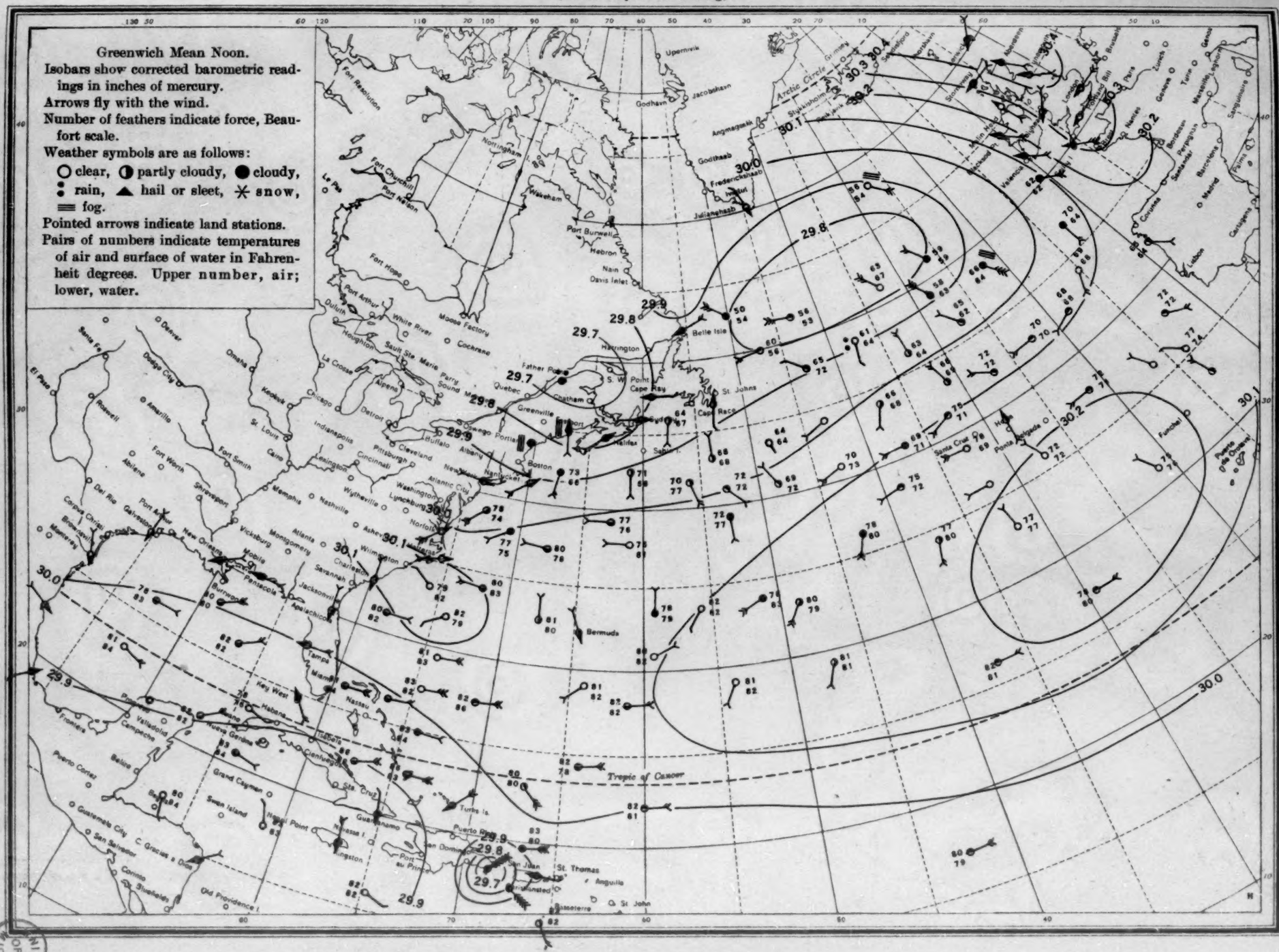


Chart XI. Weather Map of North Atlantic Ocean, September 17, 1930

(Plotted by F. A. Young)

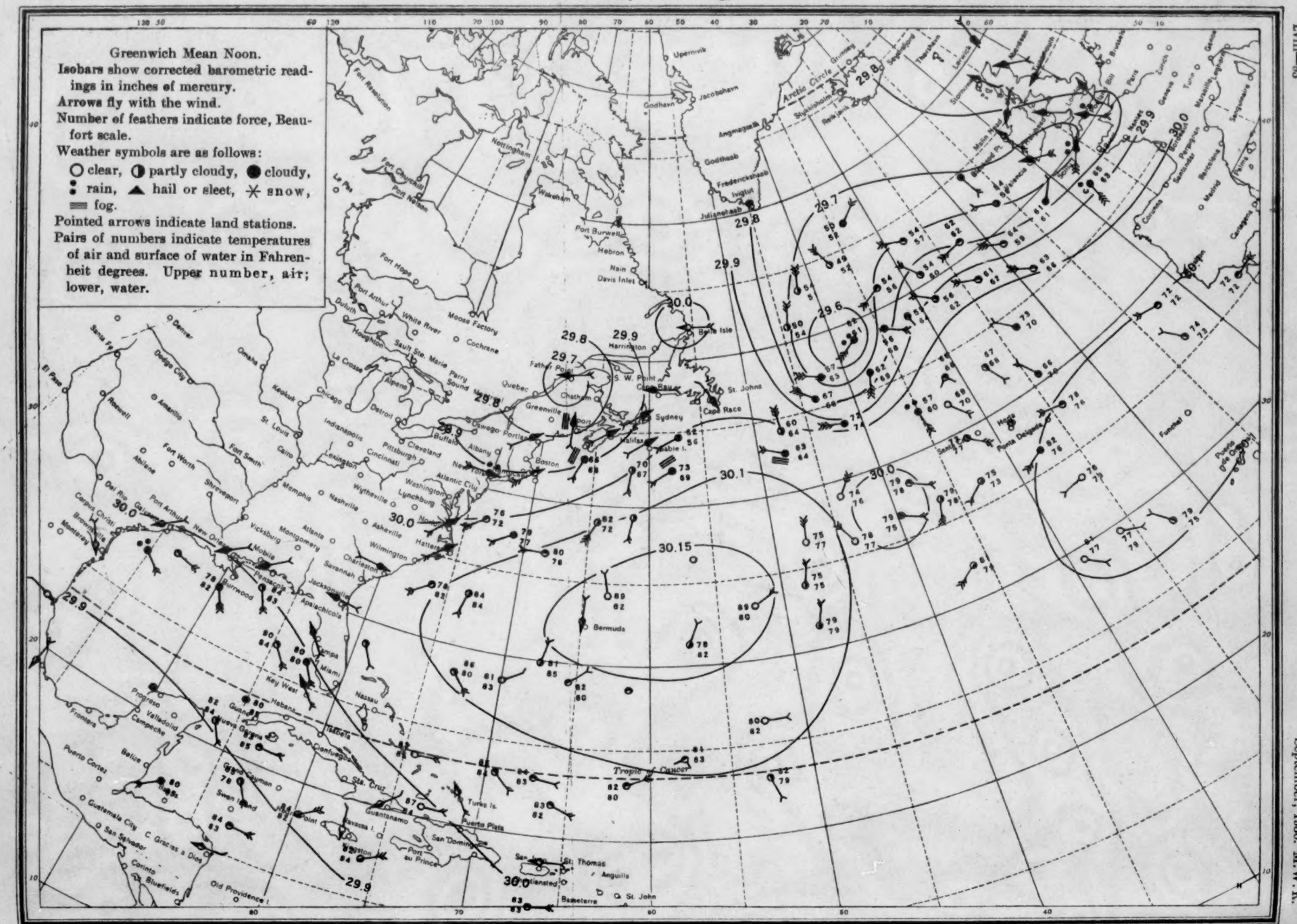

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy, rain, hail or sleet, snow, fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer
29.7
29.8
29.9
30.0
30.1
30.15
29.6

Chart XII. Weather Map of North Atlantic Ocean, September 18, 1930

(Plotted by F. A. Young)

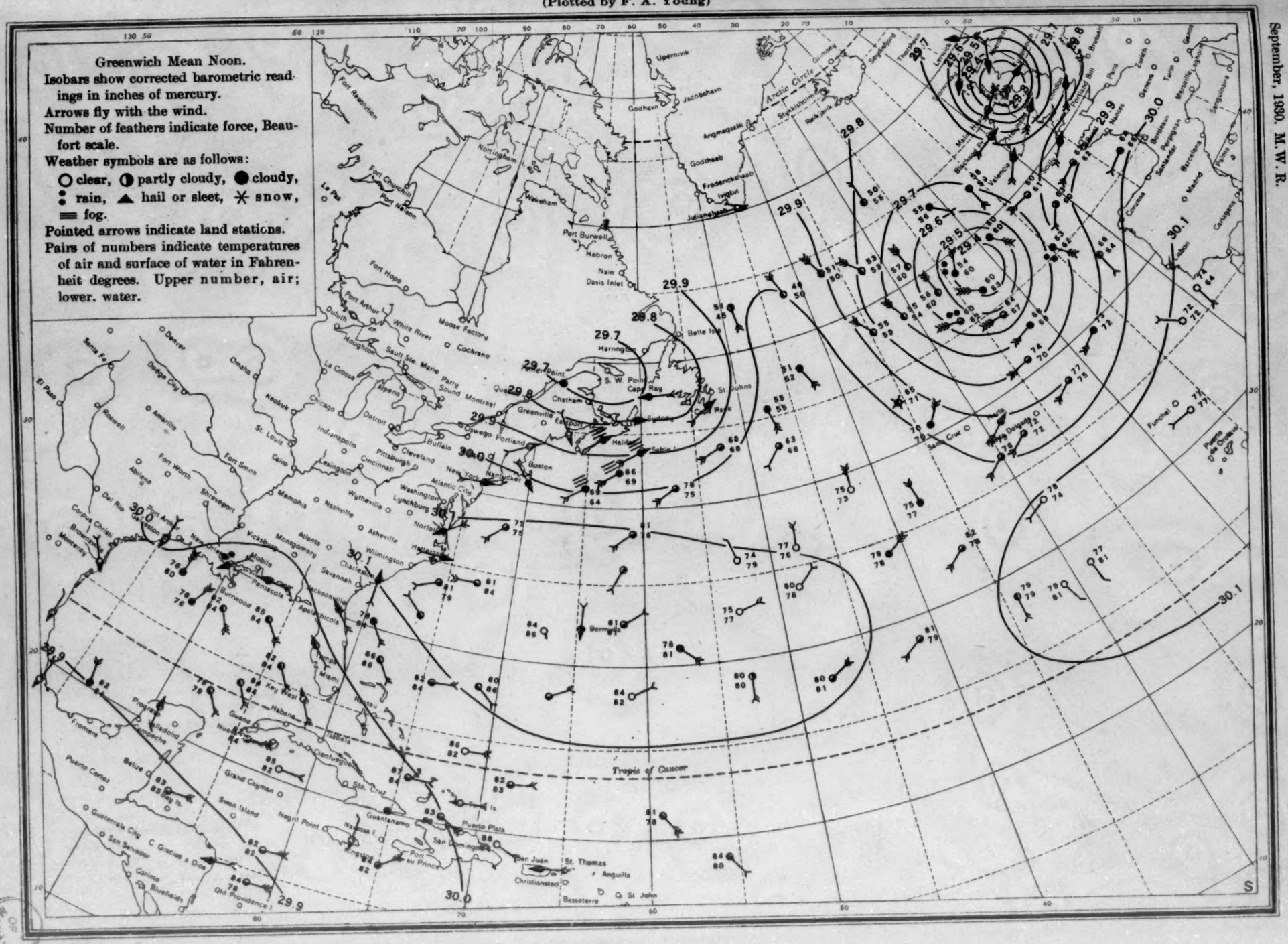
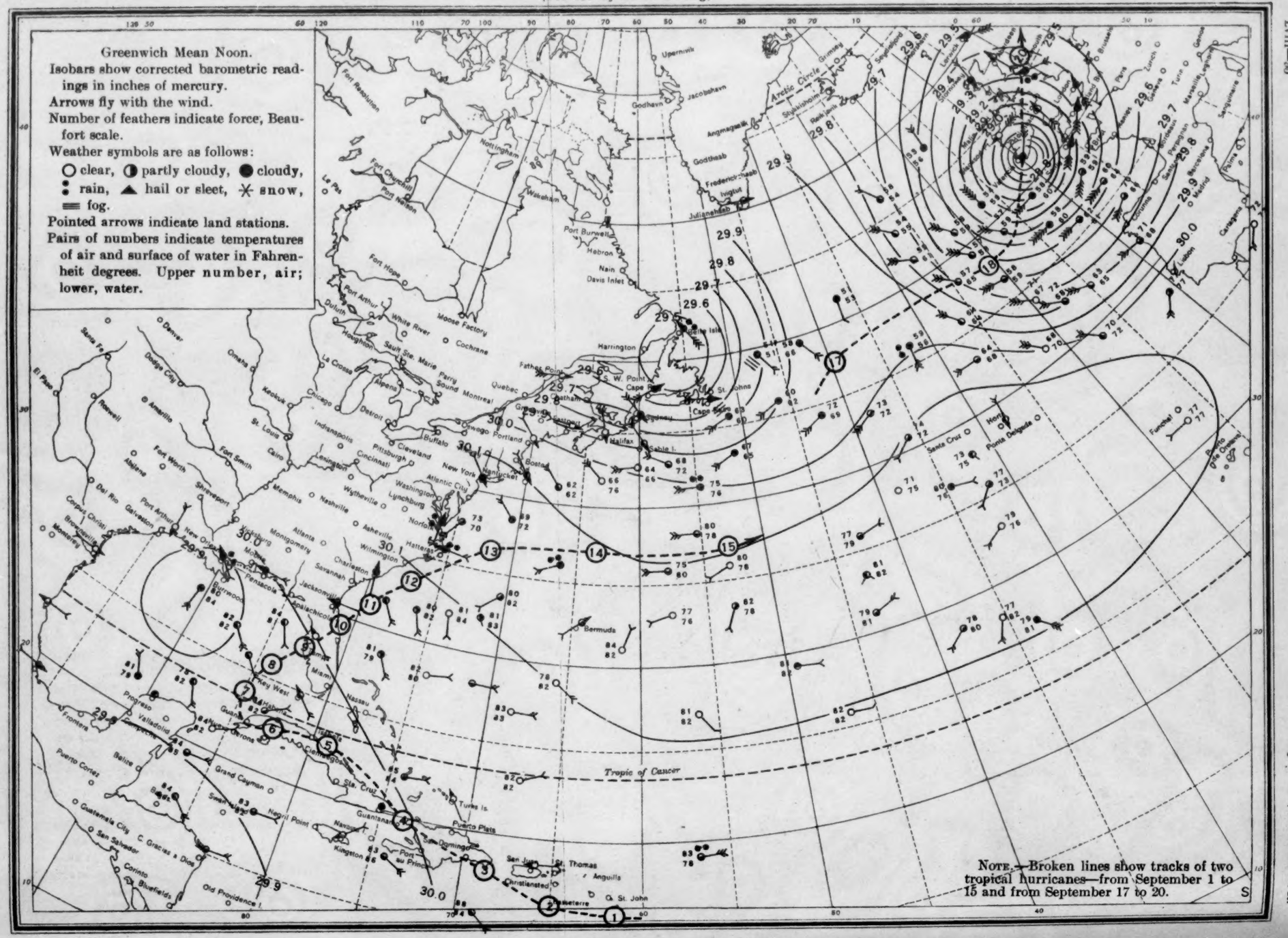

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer
Upernivik
Godhavn
Jacobshavn
Angmagssalik
Godthaab
Fredericksdal
Ivigtut
Julianehaab
Fort Resolution
Nottingham
Wakeham
Fort Churchill
Port Nelson
Le Pas
Port Burwell
Hebron
Nain
Davis Inlet
Fort Hope
Port Arthur
Duluth
White River
Moose Factory
Cochrane
Houghton
Sault Ste. Marie
Parry Sound
Montreal
Quebec
Belle Isle
Harrington
Father Point
S. W. Point
Cape Ray
St. John's
Chatham
Greenville
Eastport
Sydney
Halifax
Sable I.
Yarmouth
Boston
Nantucket
New York
Atlantic City
Washington
Lynchburg
Norfolk
Wytheville
Asheville
Hatteras
Wilmington
Charleston
Savannah
Jacksonville
Apalachicola
Pensacola
Mobile
Montgomery
Atlanta
Vicksburg
Memphis
Nashville
Lexington
Cincinnati
Pittsburgh
Cleveland
Buffalo
Oswego
Portland
Ind.anapolis
St. Louis
Cairo
Fort Smith
Keokuk
Chicago
La Crosse
Alpena
Detroit
Omaha
Dodge City
Denver
Santa Fe
El Paso
Roswell
Amarillo
Abilene
Fort Worth
Shreveport
Del Rio
Corpus Christi
Brownsville
Monterey
Port Arthur
Galveston
Burwood
Key West
Havana
Nassau
Miami
Progreso
Frontera
Campeche
Tuxpan
Tampico
Veracruz
Isabela
Cienfuegos
Sta. Cruz
Guantanamo
Puerto Plata
San Domingo
Port au Prince
Negril Point
Swan Island
Grand Cayman
Puerto Cortez
Belize
Bay Is.
Guatemala City
San Salvador
C. Gracias a Dios
Corinto
Bluefields
Old Providence I.
Ringrose
Basseterre
St. Kitts
Anguilla
St. Thomas
Christiansted
San Juan
St. John
Funchal
Puerto Delgada
Santa Cruz
Lajes
Horta
Valencia
Malaga
Cadiz
Seville
Madrid
Coruna
Santander
Bordeaux
Perpignan
Barcelona
Palma
Cartagena
Marseilles
Genoa
Turin
Zurich
Geneva
Nantes
Brest
Pointe du Raz
Portland Bill
Scilly
Falmouth
Blacksod Pt.
Valentia
Roches Point
Queenstown
Lerwick
Stornoway
Thurso
Wick
Aberdeen
Peterhead
Kirkwall
Stromness
Grimsby
Skegness
Spurn Head
Yarmouth
Hunstanton
Cromer
Harwich
Shoeburyness
Dungeness
Boulogne
Le Havre
Cherbourg
Jersey
Guernsey
Ile de Batz
Ushant
Belle Ile
Pointe de Penmarch
Les Sables d'Olonne
Rochefort
Pauillac
Arcachon
Santander
Coruna
Lisbon
Oporto
Figueira
Sagres
Gibraltar
Tangier
Casablanca
Mogador
Agadir
Cape Juby
Las Palmas
Santa Cruz
Arrecife
Porto Praya
Sao Vicente
Fernando Noronha
Pernambuco
Bahia
Rio de Janeiro
Santos
Montevideo
Buenos Aires
Bahia Blanca
Port Stanley
Punta Arenas
Valparaiso
Iquique
Arica
Callao
Paita
Guayaquil
Buenaventura
Cristobal
Colon
Puerto Limon
Port Limon
Bocas del Toro
Puerto Barrios
Progreso
Veracruz
Tampico
Tuxpan
Frontera
Campeche
Merida
Isla Mujeres
Cozumel
Belize
Puerto Cortez
Guatemala City
San Salvador
C. Gracias a Dios
Corinto
Bluefields
Old Providence I.
Ringrose
Negril Point
Swan Island
Grand Cayman
Cienfuegos
Sta. Cruz
Guantanamo
Puerto Plata
San Domingo
Port au Prince
Kingston

Chart XIII. Weather Map of North Atlantic Ocean, September 19, 1930

(Plotted by F. A. Young)



NOTE.—Broken lines show tracks of two tropical hurricanes—from September 1 to 15 and from September 17 to 20.